9-8-2007

Western and Southern Quincy Basin Regional Field Trip

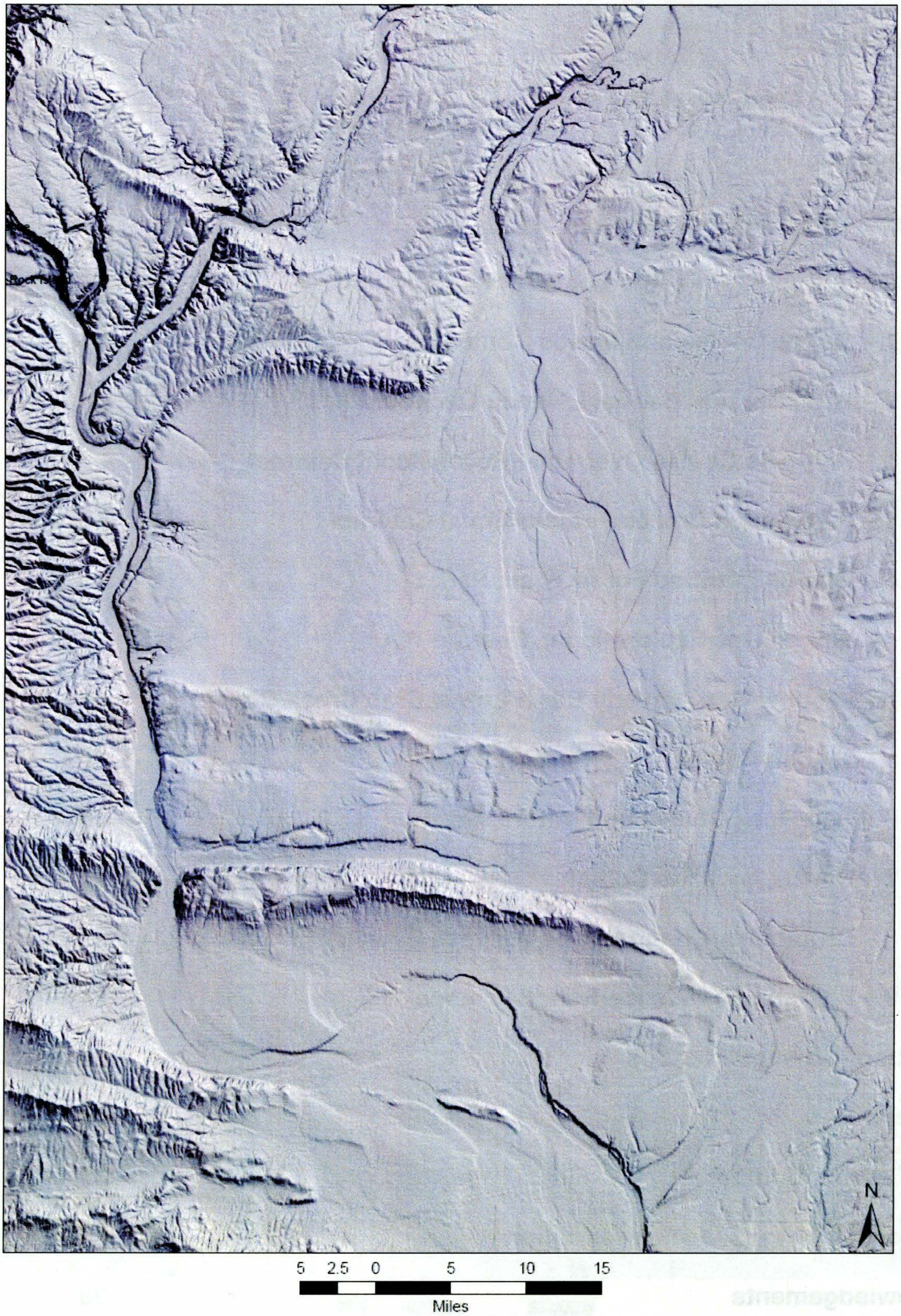
Brent Cunderla

Bruce Bjornstad

Ralph Dawes

Western and Southern Quincy Basin

Ice Age Floods Institute (IAFI) – Fall 2007 Regional Field Trip
September 8, 2007



Brent Cunderla – Geologist with USDI BLM Wenatchee Field Office
Bruce Bjornstad – Geologist with Pacific Northwest National Laboratory & Author
Ralph Dawes – Professor of Geology at Wenatchee Valley College
Wenatchee Valley Erratics (Ice Age Floods Institute) Field Trip

Table of Contents

Map Showing Major Field Trip Stops

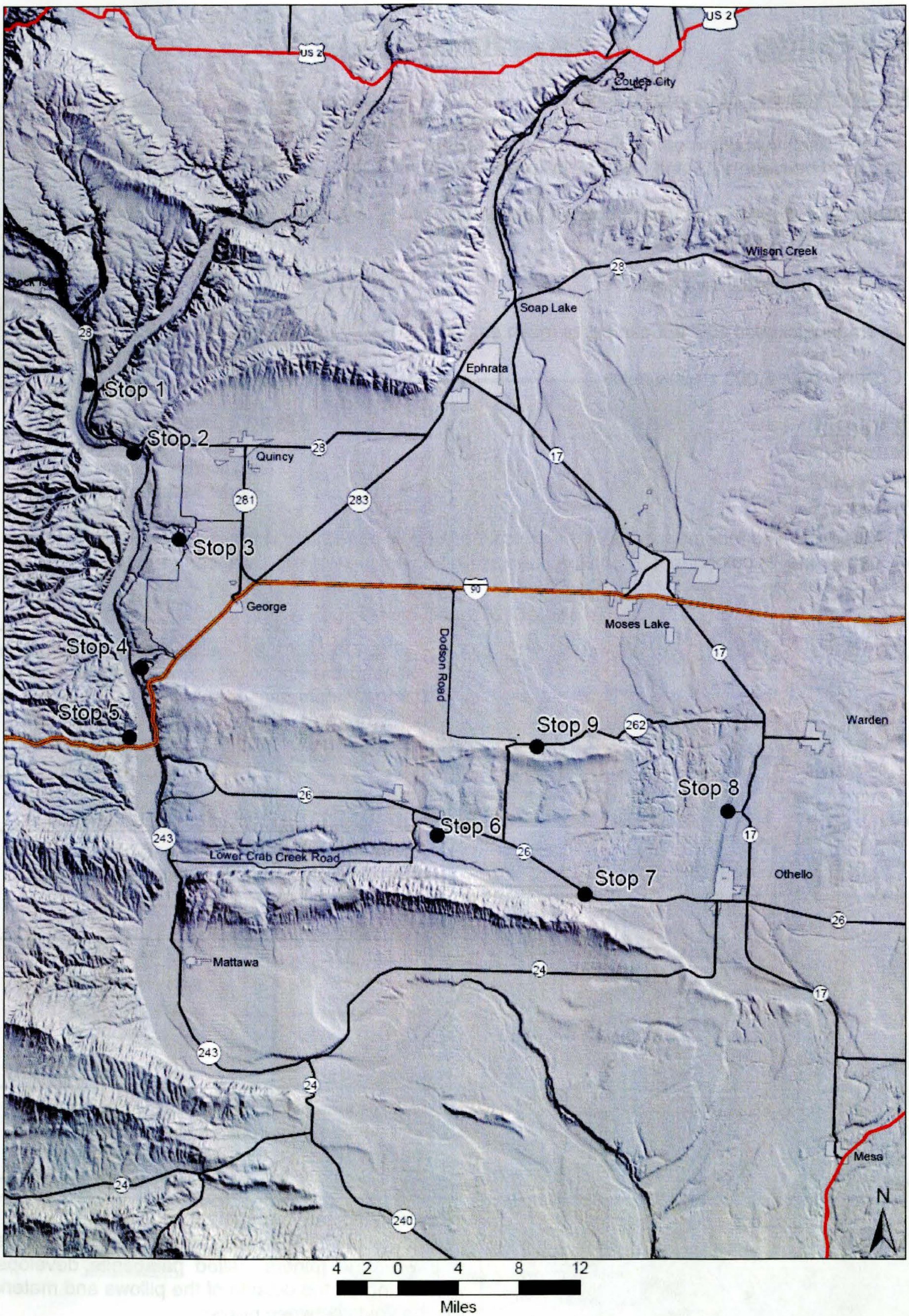


Figure 1

Field Guide

Columbia River Basalt Group (CRBG)

- Flood Basalt volcanism on the Columbia Plateau occurred between 17.5 and 6 MYBP (Miocene)
- Majority of eruptions occurred between 15.5 & 16.5 MYBP (Grande Ronde)
- Over 300 individual lava flows
- Average thickness 100' but can be as much as 300'
- Covers about 6,000 square miles

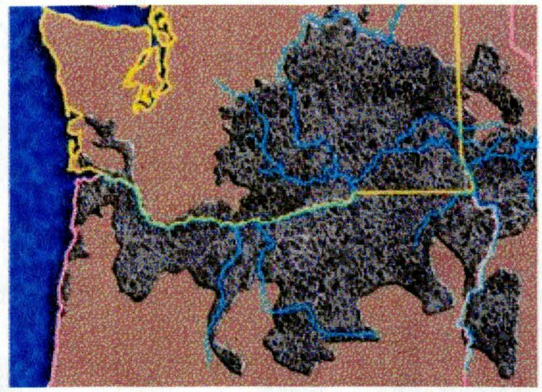
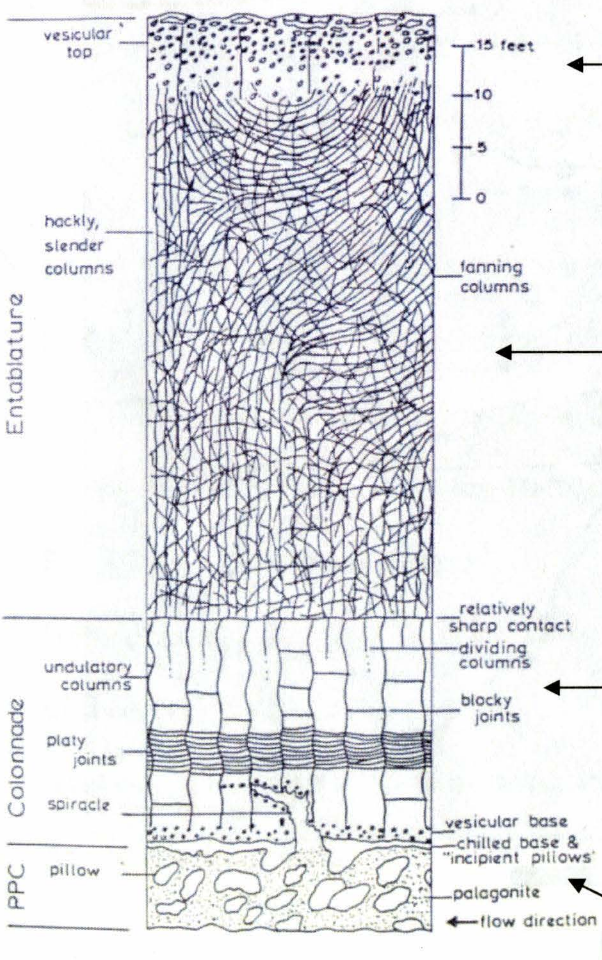


Figure 2 Extent of CRBG
Townsend & Figge (2002)
Northwest Origins
Burke Museum

Figure 3 The four main parts of the typical basalt flow consist of: 1) the lower pillow-palagonite; 2) colonnade; 3) entablature and 4) the vesicular crust. (Swanson (1967).



At the top is the vesicular crust. As gas bubbles escaped the upper portion of the flow as it cooled (almost instantaneously) leaving behind small holes or vesicles at the top of the basalt flow. This basalt is often referred to as vesicular basalt.

Above the colonnade is the entablature, which often illustrates smaller radiating, or fanning columns.

The colonnade consists of very straight, often well-developed vertical columns that formed in the center part of the basalt flow.

When molten magma came in contact with water (lake, swamp, etc.), a pillow-palagonite layer was formed. A yellow-orange mineral called palagonite develops from weathering on the outside of the pillows and material that fills the voids between pillows.

Pleistocene Epoch "Ice Age"

- Lasted about 2.6 MYBP to 13,000 years before present
- Most recent Ice Age Flooding - 13 to 15,000
- Evidence for at least 100 catastrophic floods
- Average time between floods was 40-60 years
- Recent Evidence for older catastrophic flooding
    - May be as early as 1.5 – 2.5 MYBP
    - Early Pleistocene 780 TYBP
    - Middle Pleistocene 130 TYBP

Catastrophic Ice Age Floods

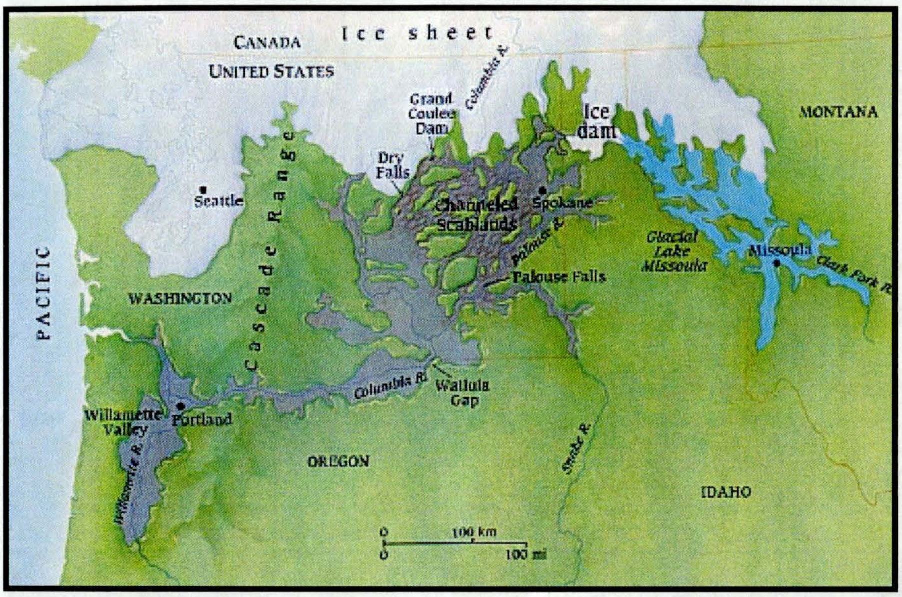


Figure 4
Smithsonian Magazine
April 1995
The Floods that Carved the West
By Michael Parfit
Page 50

Cordilleran Ice Sheet and Missoula Floods

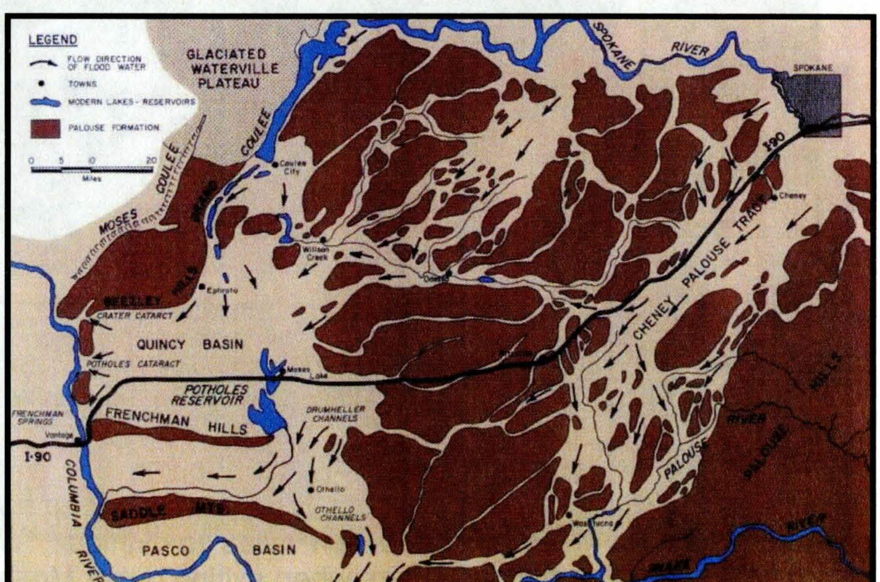


Figure 5
Between the Mountains - A portrait of Eastern Washington
1975
By John Alwin
Page 27

Channeled Scabland

Moses Coulee Bar

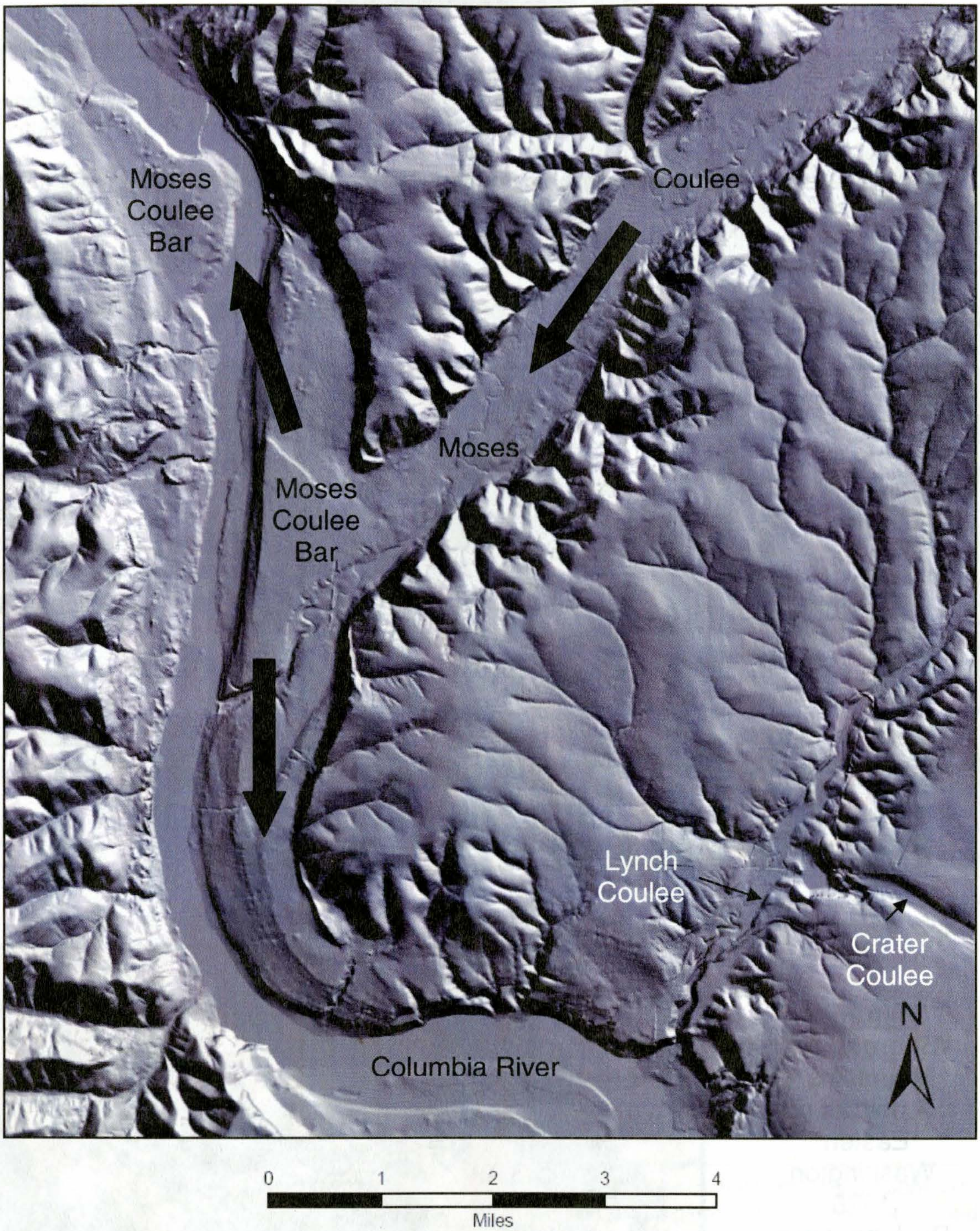


Figure 6 - Digital Elevation Model – Lower Moses Coulee & Gravel Bar

Image shows lower portion of Moses Coulee and large gravel bar (fan) emanating from the coulee mouth. The bar expanded both up valley to Rock Island and downstream about ten miles to Trinidad, Washington. Arrows indicate direction of floodwaters when exiting out of Moses Coulee.

STOP 1 – Moses Coulee and Moses Coulee Bar

The lower end of Moses Coulee, almost 1 mile wide and 750 feet deep, shows magnificently flood-truncated spurs between hanging tributaries.

The deposit at its mouth is the dissected main remnant of a great fan built by floods out of Moses Coulee (Bretz, 1930, 1969). See Figure 6. The high part of the deposit stands well out into Columbia River valley. The gravel is almost entirely basalt, evidence of derivation from Moses Coulee, not from the up valley Columbia. During glacial advance, the Okanogan Lobe blocked the Columbia valley but not yet the Moses Coulee intakes. Floodwater could not descend the Columbia during the Moses Coulee floods, so these floods built a great fan across and *up* the Columbia River, evidently blocking it.

But the surface of the bar is marked by giant current dunes whose steeper down valley slopes indicate *down* valley flow. Therefore this early-glacial bar was overtopped in late-glacial time by great flood that mainly reworked the basaltic gravel. This surficial reworked gravel extends into a fan that diverges into and *up* Moses Coulee, showing that no great flood simultaneously poured down Moses Coulee. This late flood is doubtless that which overtopped Rock Island bar just up valley and which overtopped the "great terrace" up valley of Entiat.

Lower Moses Coulee

The thick sequences of Miocene "flood basalts" that blanket the Columbia Plateau (Figure 2) belong to the Columbia River Basalt Group which range in age from 17.5 to 6 m.y.b.p. (Reidel, 1989). This sequence of basalts is further subdivided into the Yakima Basalt Subgroup (Reidel, 1989) consisting of three formations (from oldest to youngest): Grande Ronde Basalt; Wanapum Basalt and Saddle Mountains Basalt. The basalt flows (Figure 3) visible in the lower coulee walls belong to the upper "series or members" with "normal magnetic polarity" which are the youngest of the Grande Ronde Basalts (older than 15.6 m.y.b.p.). Note the formation of large talus slopes that have developed along the coulee walls since the last ice age floods, predominately from the seasonal freeze-thaw cycle.

Hanson (1970) hypnotized that the pre-flood drainage for Moses Coulee was similar to what occurs in the Rock Island Creek drainage (next major drainage to the west) today. It is believed that there was an established drainage within Moses Coulee prior to ice age flooding, unlike Grand Coulee where the coulee itself formed along a structural fold (Barker or Coulee Monocline).

Figure 7 – Google image of Lower Moses Coulee. View is northeast.

West Bar and Babcock Bench

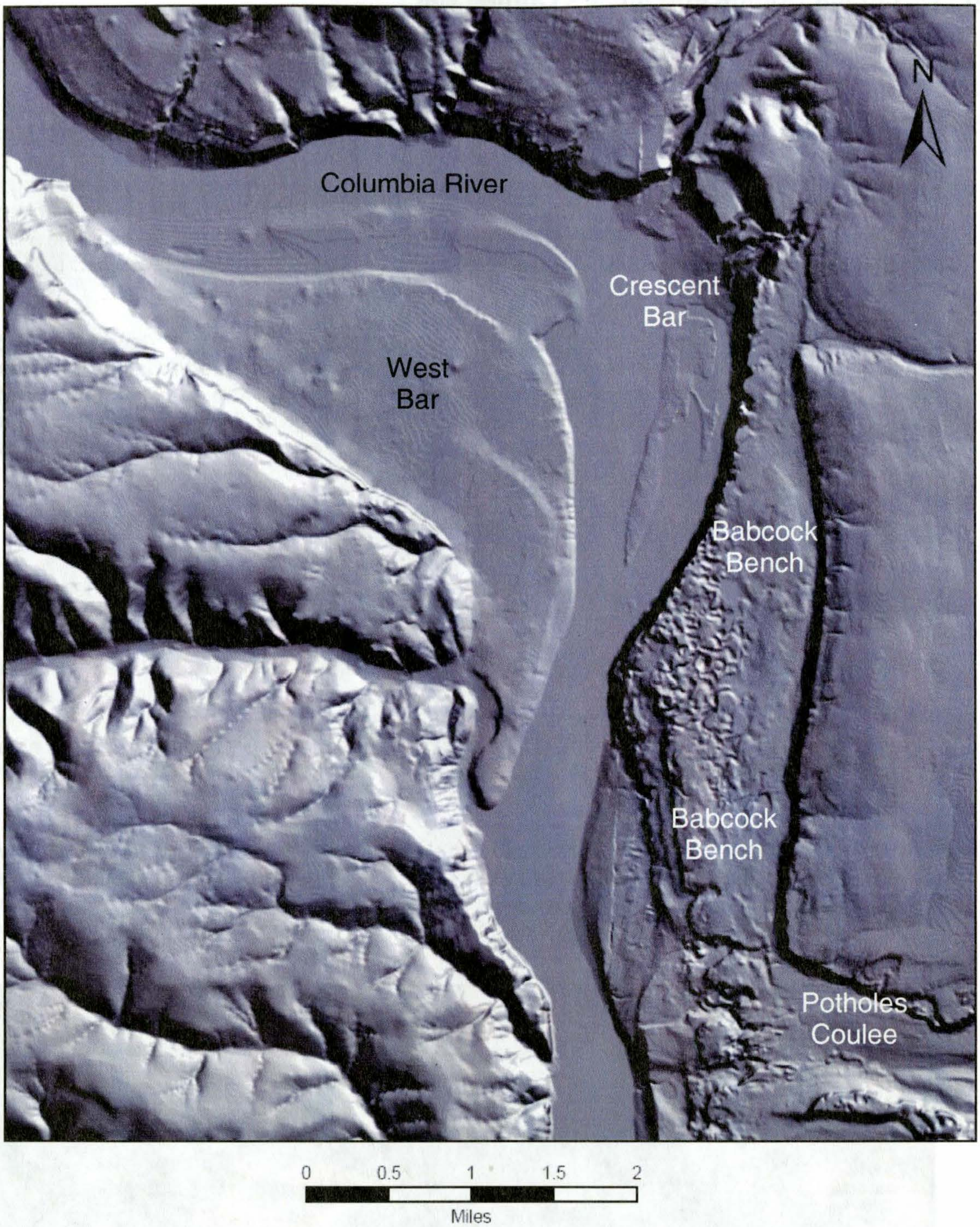


Figure 8 - Digital Elevation Model – West Bar & Babcock Bench

Image shows "West Bar" that was formed by late Ice-Age flooding down the Columbia River drainage as floodwaters made this 90° corner at Trinidad, Washington. Babcock Bench is an erosional flat surface in the basalt bedrock along the eastern bank of the Columbia River.

STOP 2 – **West Bar and Babcock Bench Overlook** – Gravel Bars, Current Dunes & Scabland Topography

Excerpt from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p.

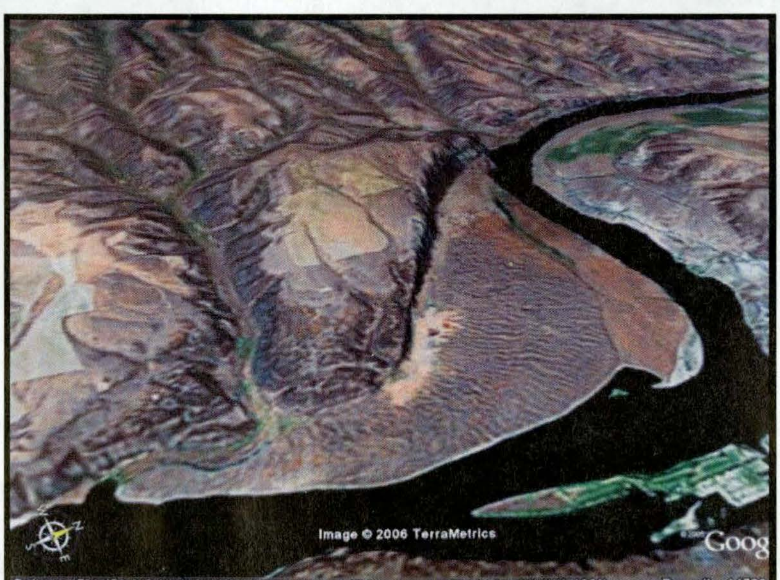
West Bar Giant Current Ripples

Clearly visible giant current ripples blanket West Bar, a giant flood bar along the Columbia River. See Figures 8 and 9. West Bar is one of the best and most-classic examples of giant current ripples anywhere along the paths of the Ice-Age floods. The ripples average about 25 feet in height, 350 feet apart, and are composed of boulders up to 4.5 feet in diameter. The ripples atop West Bar lie 150 to 250 feet above river level. Based on ripple size and spacing, geologists estimate the water could have been as much as 650 feet deep when the ripples formed.

The shape and orientation of the West Bar giant current ripples indicate they formed from a last Ice-Age flood that came down from the north via the Columbia River Valley. While Scabland floods did come down from the north via Moses Coulee, these floods came early in the last glacial cycle, not at the end. Therefore, the flood that created West Bar's giant current ripples must have been from a Columbia flood and not a Scabland flood from Glacial Lake Missoula. The flood that created these ripples may have come from a post-Missoula flood breakup of Glacial Lake Columbia (lake impounded behind Okanogan lobe) or possibly from a sub-glacial outburst, or some other as yet unidentified source.

Babcock Bench

Babcock Bench, up to 1 mile wide, is an elevated, flood-swept rocky terrace that can be traced along the east side of the Columbia River for about 20 miles (Figure 8) shows northern portion). This feature begins near Trinidad on the north and continues to within a few miles of Vantage on the south. Ice-Age floods eroded layers of basalt down to the more resistant entablature portion of the basalt flows. The floodwaters plucked away and transported larger, massive blocks of columnar basalt. Most of Babcock Bench is composed of the more flood-resistant entablature atop the Sentinel Bluffs Member of Columbia River basalt.



<u>Figure 9</u> - Image from Google Earth showing West Bar Ripples.
View is northwest.

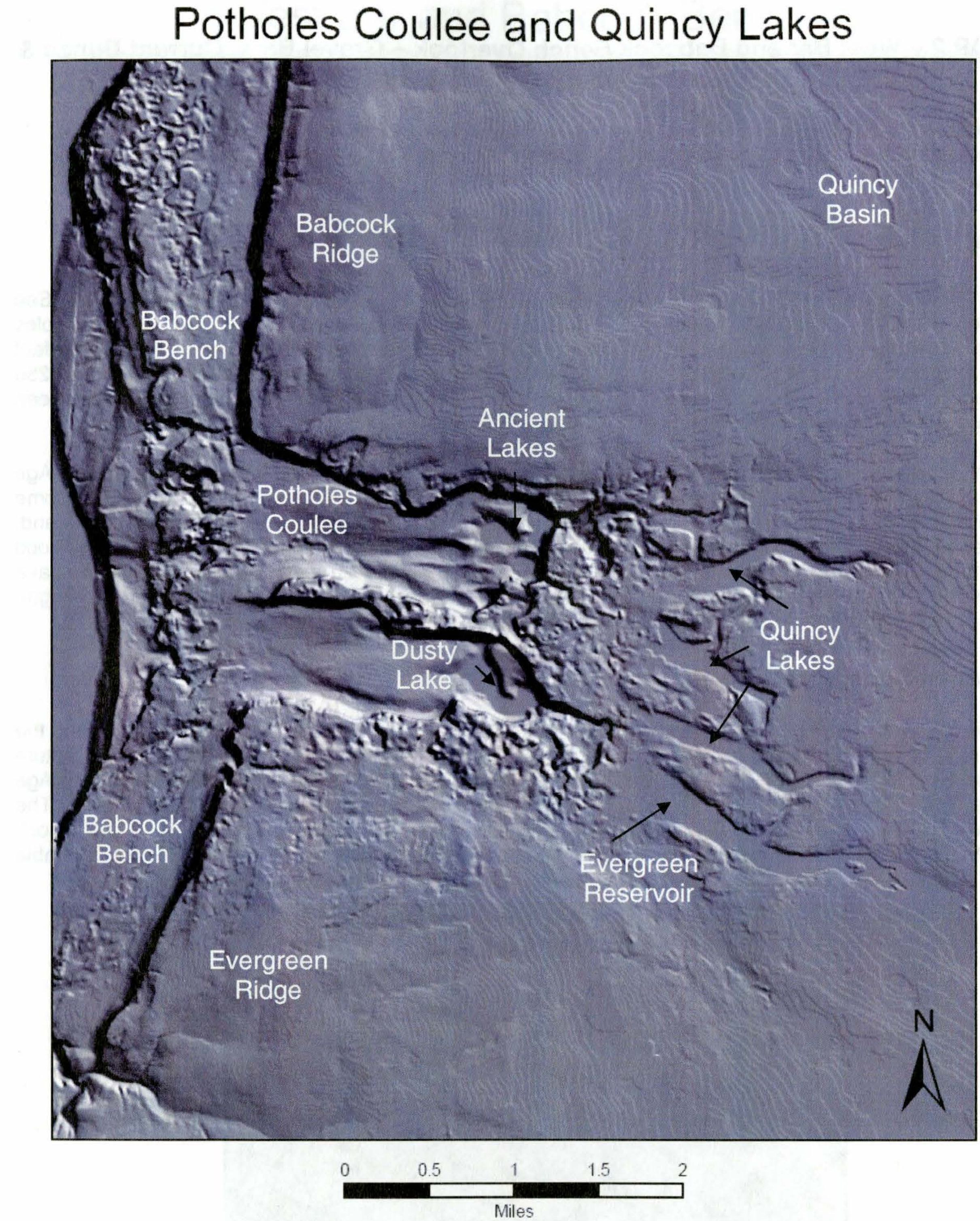


Figure 10 - Digital Elevation Model – Potholes Coulee & Quincy Lakes

Image shows Potholes Coulee one of the two main outlets that floodwaters emanated from along the west side of the Quincy Basin. Potholes Coulee is very similar in morphology to Dry Falls of Grand Coulee with a double cataract.

STOP 3 – Potholes Coulee – Recessional Cataract

Excerpt from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p.

Potholes Coulee

The drainage divide into Potholes Coulee (1200 feet) is the lowest of three coulees that steeply descent into the Columbia Valley from the Quincy Basin. Potholes coulee, and its neighbors, Crater Coulee and Frenchman Coulee, are spectacular, horseshoe-shaped, tiered, cataract canyons that developed when floodwaters quickly rose up to 1425 feet elevation and overtopping several divides across Evergreen and Babcock ridges. When this happened, an incredible drop of over 850 feet was created over a distance of less than 3 miles between the Quincy Basin and the Columbia River valley to the west! With this difference in water level over such a short distance, floodwaters furiously ate away at the underlying basalt layers, and their vain attempt to establish hydraulic equilibrium across the divide. Any topsoil present was completely stripped away, along with hundreds of feet of basalt bedrock, carving a deep chasm between Babcock and Evergreen ridges.

Potholes Coulee consists of two, parallel, amphitheater-shaped, cataract-lined alcoves (Figures 10 & 12). Separating the two alcoves in Bretz's words is "a great blade of rock a mile and half long, 1,000 feet wide, and 375 feet in maximum height between them." The upper ends of these alcoves form the Ancient Lake Basin on the north, and Dusty Lake Basin on the south. An upper cataract steps up from these alcoves, forming a wild maze of butte-and-basin scabland all the way up to Quincy Lakes. Deep plunge pools lie at the bases of some cataracts. Beyond the cataracts are huge bars of coarse-grained flood deposits, which blanket the bottom of both alcoves westward to Babcock Bench. Many of the bars, rising up like the backs of giant whales, are covered with giant current ripples. Elongated depressions (fosses) developed between flood bars and the coulee walls (Figure 12).

Three sets of recessional cataracts are preserved in 2-mile-wide Potholes Coulee. The upper cataract developed across the Roza Member of Columbia River basalt and in places receded as much as 3 miles – all the way to Quincy Lakes. One characteristic of the Roza Member is its especially massive basalt columns that can be several feet wide. A middle cataract developed across the Frenchman Springs Member, the next oldest basalt member. In some places, these two cataracts are stacked on top of each other, forming a single cataract up to 400 feet tall! This stacking is visible immediately above Dusty and Ancient Lakes and where the basalt rib separates the north and south alcoves. A lower cataract stepped down into the next oldest basalt member (Sentinel Bluffs) near the mouth of Potholes Coulee along the west side of Babcock Bench. The lower cataract appears to have begun to retreat up the coulee when the last scabland floods occurred and prematurely cut off its development. During the next cataclysmic Scablands floods these cataracts will likely resume their retreat up the coulee, lengthening it eastward.

Quincy Lakes

Floodwaters that overtopped Evergreen and Babcock Ridges formed the three Quincy Lakes (Stan Coffin, Quincy, and Burke Lakes) and Evergreen Reservoir. The mouths of the lakes mark the eastern extent of cataract recession in Potholes Coulee.

Quincy Lakes were created as floodwaters picked up speed as they were funneled through narrow Potholes Coulee. Floodwaters moving at a higher speed led to erosion, scouring out the lakes. Much less erosion occurred east of the lakes because floodwaters here moved more slowly across the wide expanse of the Quincy Basin. The slow speed of the floodwaters in the central Quincy Basin is why no well-developed scabland features are found here. Instead of erosion, the floods mostly deposited sediment in the center of the basin.

Frenchman Coulee

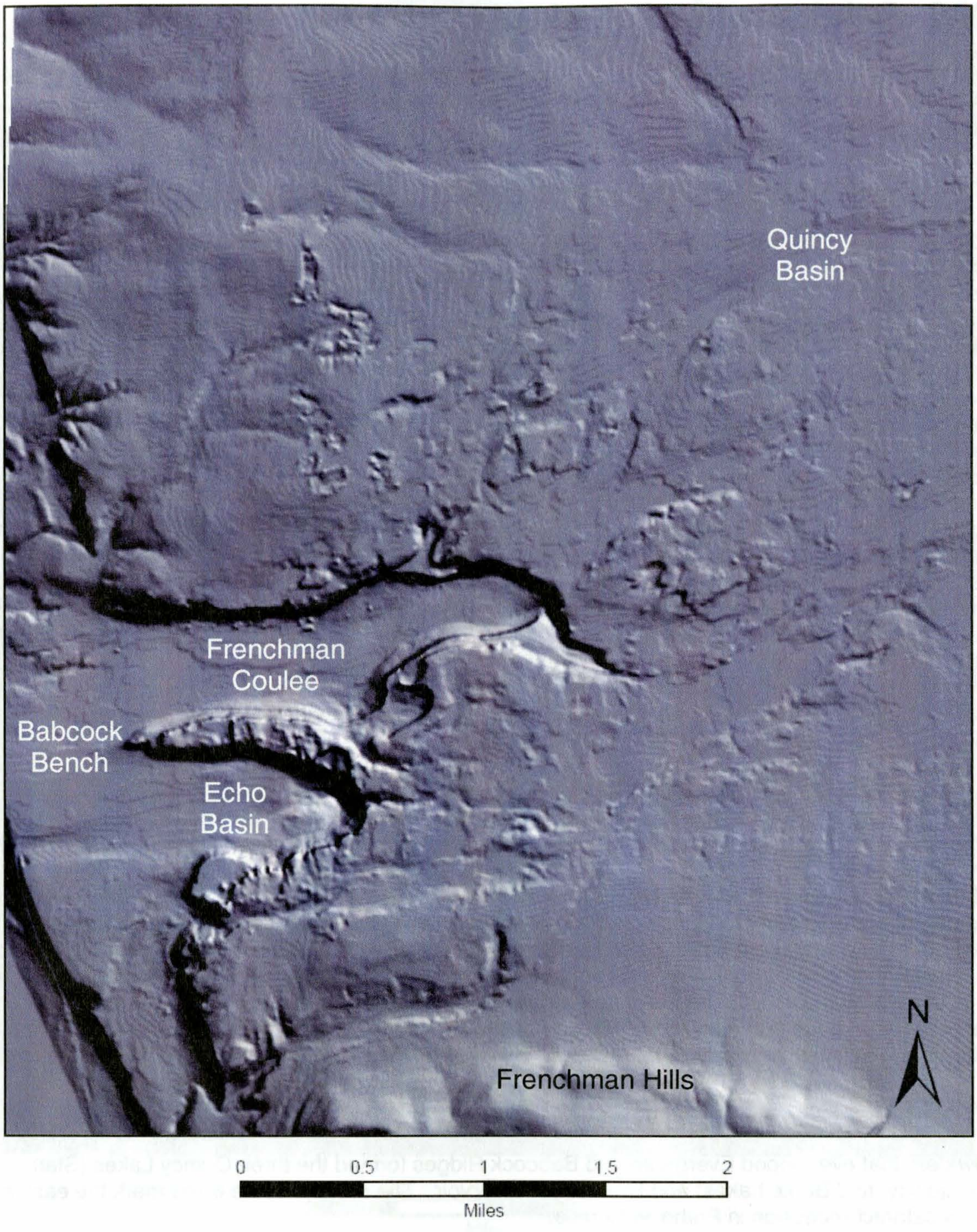


Figure 11 - Digital Elevation Model – Frenchman Coulee

Image shows Frenchman Coulee the other main outlet for floodwaters along the west side of the Quincy Basin. Again note that Frenchman Coulee is another double cataract system.

<u>STOP 4</u> – <u>Frenchman Coulee</u> – Recessional Cataract

Excerpt from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p.

Frenchman Coulee

Frenchman Coulee, also known as Frenchman Springs Coulee, is a dual coulee and cataract system. Like its neighbor to the north, Potholes Coulee, Scabland floods created Frenchman Coulee when they spilled westward over a low divide across Evergreen Ridge, where it butted up against the Frenchman Hills. During initial stages of flooding, the difference in water levels between the flood-filled Quincy Basin and the Columbia River immediately west of the Evergreen Ridge approached 700 feet over just a few miles. This incredible difference in water levels caused floodwaters to relentlessly eat away the underlying rock layers. Erosion continued for at least as long as it took for the water level in the Columbia Valley to rise to about 1200 feet, or until the floodwater supply was exhausted. See Figure 11.

Landforms created during flood erosion around Frenchman Coulee include spillover channels, hanging coulees, recessional cataracts with inner channels, plunge pools, pillars, rock basins, benches, and potholes. Depositional flood features include giant flood bars and fosses.

Two cataract cliffs (waterfalls during Ice-Age floods) are present in Frenchman Coulee. (Figure 13) The upper cataract is across the Roza Member, while the lower developed across the Frenchman Springs Member. In some places, the two cataracts merge to form a single tall cataract up to 400 feet high. Elsewhere, a rock bench separates the two cataracts and basalt members. These cataracts started at the mouth of the coulee and receded as much as 2 miles east up the coulee during subsequent floods. Another characteristic feature of Frenchman Coulee is a flood-scoured rib, or blade of basalt that separates the main Frenchman Coulee from Echo Basin (Figure 11). An almost identical basalt rib also separates a pair of recessional cataracts at Potholes Coulee, a few tens of miles north of here.

Frenchman Coulee is a dual coulee-cataract system. On the north is the main Frenchman Coulee and to the south, Echo Basin (Figures 11 & 13). Amphitheater-shaped alcoves lie at the heads of the coulees. A third, less-well-developed alcove, the middle alcove, lies between (Figure 13). Running down the center of the middle alcove is the "Feathers". The Feathers separate two smaller basalt-rimmed amphitheaters within the middle alcove. The columns are especially popular with rock climbers, who may be dangling off the sides of the huge columns.

Plunge pools are found below some of the cataracts. Beyond the cataracts, coarse-grained flood deposits blanket the bottom of the alcoves to Babcock Bench, similar to Potholes Coulee. The flood deposits were laid down as giant flood bars with deep troughs (fosses) between some of the flood bars and the steep coulee walls.

Huge, house-sized boulders of basalt are scattered along the bottom of Frenchman Coulee and out onto Babcock Bench. Some of these may have been ripped away from the cataract walls and transported short distances during flooding. Others, however, especially those close to coulee walls, may have simply tumbled off the unstable, steep walls into the coulee since the last Ice-Age flood.

Of special interest is a high, sculpted-out area in the steep wall of basalt, visible on the opposite side of the Columbia River from Frenchman Gap. Like a giant fire hose, a forceful jet of floodwater hit this rock wall head on after cascading through Frenchman Coulee. See Figure 13, Point of Interest A.

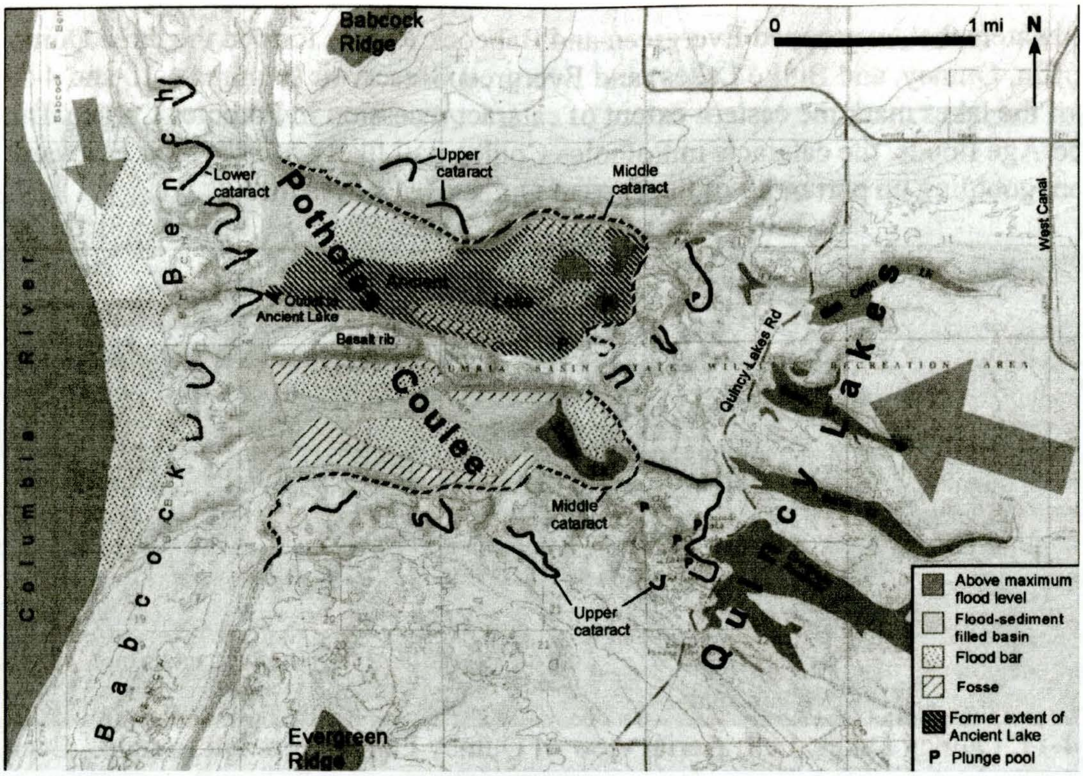


Figure 12 From *On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, Guide to the Mid-Columbia Basin. Figure 4-11, Page 79

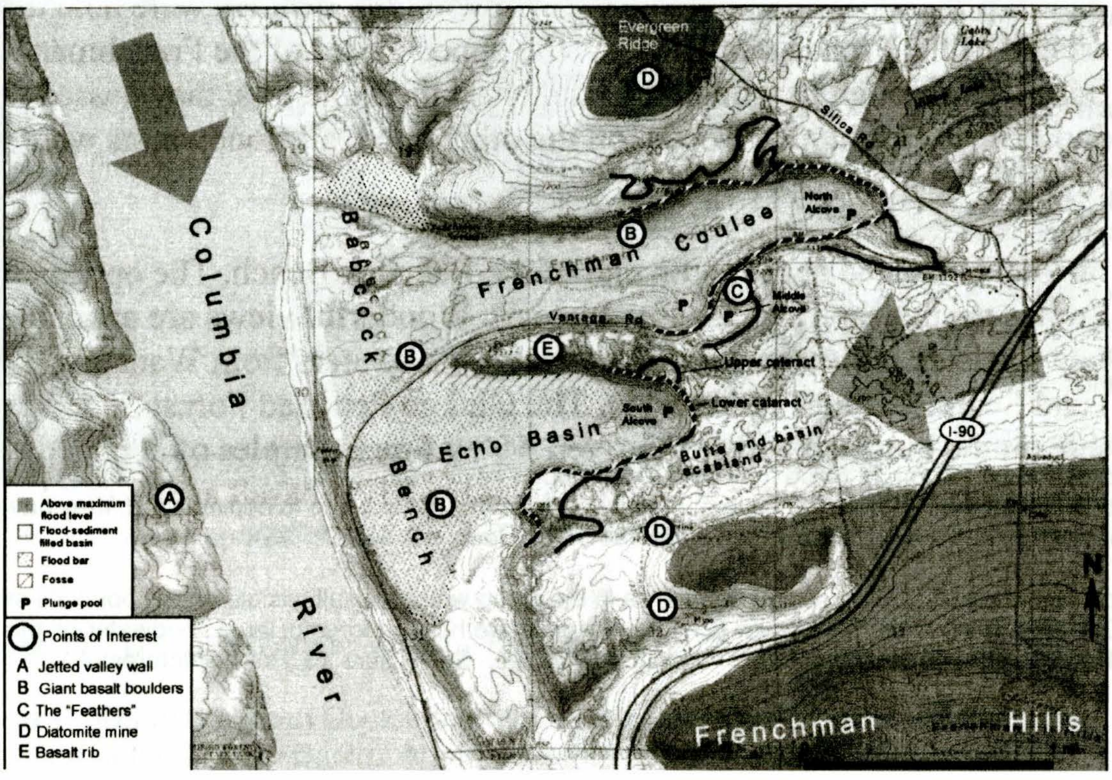


Figure 13 From *On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, Guide to the Mid-Columbia Basin. Figure 4-14, Page 83

STOP 5 – Gingko Petrified Forest State Park

Excerpt from "*Geology of the Vantage area, south-central Washington: An introduction to the Miocene flood basalts, Yakima Fold Belt, and the Channeled Scabland*" by Robert Carlson, Terry Tolan and Stephen Reidel, 1987, Geological Society of America Centennial Field Guide – Cordilleran Section, 1987, pages 357-362.

Stratigraphy

The oldest exposed rocks in the Vantage area are the tholeiitic flood basalt flows (Figure 2) of the Miocene Columbia River Basalt Group (CRBG) (Waters, 1962). It has been estimated that more than 60,000 mi^3 of CRBG lava was erupted from fissures and vents in eastern Washington (Tolan and Reidel, 1985), western Idaho, and northeastern Oregon (Figure 2) from about 17.5 to 6 m.y. ago. The combination of large volume, low viscosity, and high temperature of the erupting lavas enabled them to cover more than 62,200 mi^2 in Washington, Idaho, and Oregon (Tolan and Reidel, 1985, unpublished date). More than 99 percent by volume of the CRBG lavas were erupted over a very short period – from about 17.5 to 14.5 m.y. ago. Changes and variations in the geochemical compositions, paleomagnetic polarity, and physical characteristics of the CRBG flows have allowed for their division into five formations and 14 members (Swanson and others, 1979). The Vantage area is underlain by 5,000 ft. to more than 10,000 ft. (1,500 to more than 3,000 m) of Columbia River basalt which can be divided into Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt.

Yakima Fold Belt

The Yakima Fold Belt consists of a series of generally east-west-trending anticlinal ridges and synclinal valleys that were produced under north-south regional compression. These folds extend from the western half of the Columbia Plateau into and through the Cascade Range (Reidel, 1984).

The anticlinal folds are typically asymmetric, with a thrust or high-angle reverse fault(s) along the steeper limb. The fold geometry can vary from open to tight and the folds are typically segmented. The narrow anticlinal ridges are separated by synclinal valleys that are in many cases very broad, flat basins.

Detailed studies of several Yakima folds on the Columbia Plateau (Reidel, 1984) have revealed that they have had a long, complex deformational history. Evidence indicates that these folds were developing since at least Grande Ronde time (16.5 to 15.5 m.y. B.P.).

Ginkgo Petrified Forest State Park

The Ginkgo Petrified Forest State Park is an area of excellently preserved Miocene (15.5 m.y. old) petrified wood that notably occurs in a basalt pillow complex of the Ginkgo Flow of the Frenchman Springs Member. The two sites described here on the state park grounds provide excellent opportunities to examine the petrified wood both in its original geologic setting and in museum exhibits.

Outside and behind the museum is a scenic overlook from which one can see most of the area covered by this field guide. Far to the north on the east side of the Columbia River is the mouth of Frenchman Coulee. Frenchman Coulee is a cataract which was carved out by catastrophic flood waters as they poured into the Columbia River channel from the east. Directly across the river from here can be seen Babcock Bench which is a stripped structural surface created by the catastrophic floods. Below the bench are N_2 Grande Ronde Basalt flows and above the bench are flows of the Wanapum Basalt. The break in the cliffs to the southeast is the mouth of Sand Hollow. Far to the south, beyond Wanapum Dam, is Sentinel Gap – a water gap through the Saddle Mountains.

Within the Ginkgo pillow complex are found petrified woods representing a diverse assemblage of conifers and deciduous trees – more than 50 genera may be present within the ginkgo pillow complex (Beck, 1945).

EnCana (Energy Canada) Brown 7-24 Natural Gas Exploration Well

Oil and Gas activity within eastern Washington is expanding. A majority of Federal, State and private lands and mineral estate encompassing over one million acres have been leased within the Columbia Basin (about 650,000 acres federal lands and mineral estate). The principal companies involved in the leasing of the Federal lands are Savant Resources, Energy West, and EnCana Oil & Gas.

In the late 1980's major companies (Shell Exploration) ended there exploration and drilling program in eastern Washington due to the following:

- Seismic exploration was difficult through the thick covering of basalts (lava flows) that overly sediments beneath the basalts.
- Thick accumulation of flood basalts (greater than 5,000-10,000 feet) overlying Tertiary continental sediments were extremely expensive to drill through.
- Even though nine deep wells (over 5,000 feet) were drilled that have penetrated the sediments and most had gas shows, none of the wells were considered "commercial".

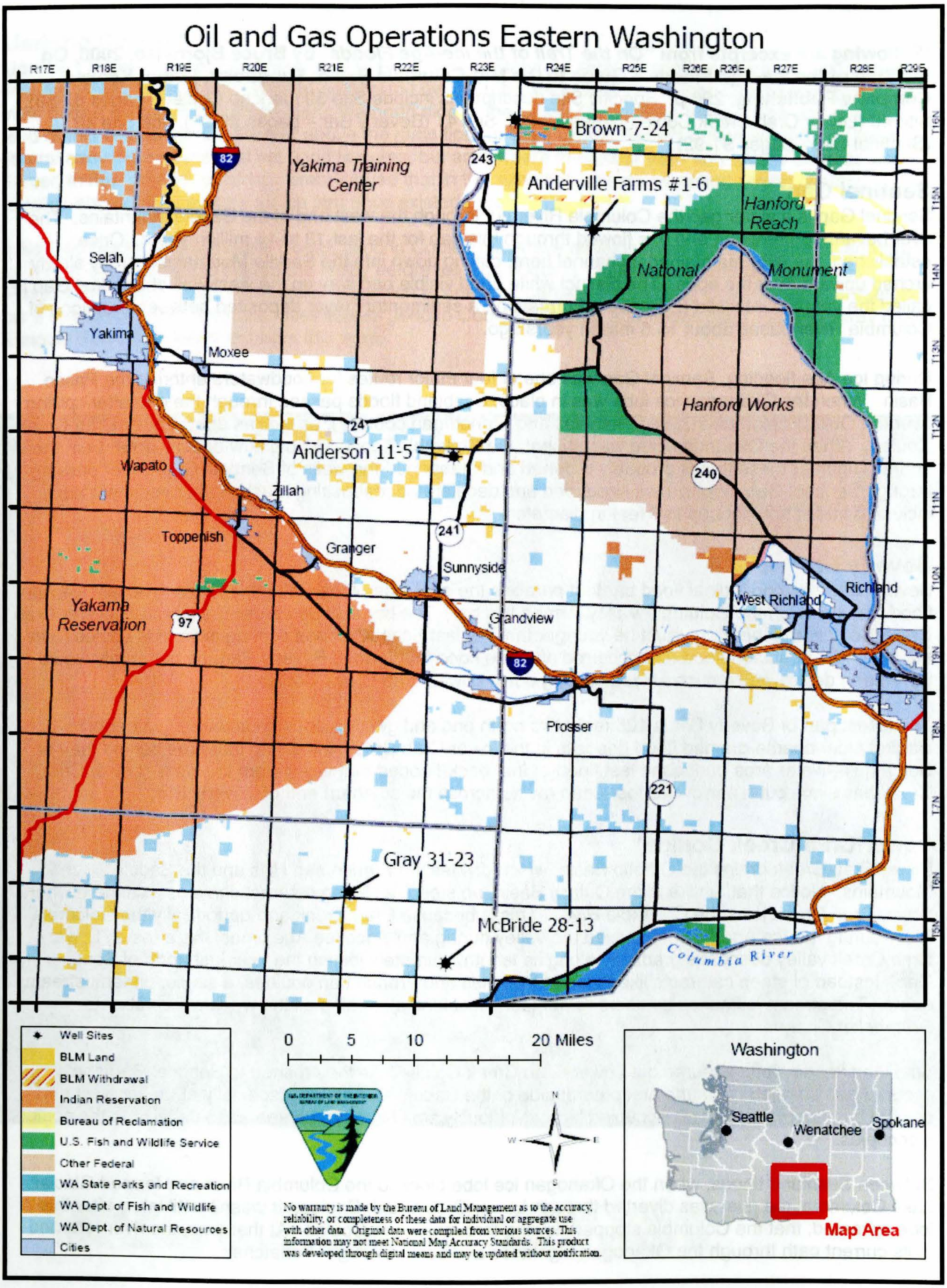
Area is Attractive Now:

- Price of natural gas and predicted shortage since Canada is using more rather than exporting it.
- Improved drilling using a newly developed drill rig that will more efficiently drill through the thick basalt cap.
- USGS has estimated the Columbia Basin contains over 12 trillion cubic feet of gas in the huge structures (anticlines). The anticlines are among the largest prospective structures of natural gas remaining in North America.
- The area basically is unexplored.

After leasing, the companies initially started conducting geophysical work, principally magneto tellurics (MT) to look for larger targets for wildcat exploration well locations. EnCana USA was the first company to announce a drilling program venture within the Columbia Basin and planned three exploration wells (permitted to 14,000 feet) to further define exploration targets. EnCana initially drilled the Anderville Farms, Inc. # 1 well, located on private agricultural land about seven miles west of Mattawa. EnCana's second well, the Anderson 11-5 is located on the southern flank of the Rattlesnake Hills north of Sunnyside, Washington. The Brown 7-24 well is the third well of EnCana's drilling program. Additional drilling efforts by EnCana USA, Inc. will depend on further testing at the three wells. Delta Petroleum Company more recently entered into an exploration drilling program with two wells (Gray 31-23 & McBride 28-13 wells) planned in eastern Klickitat County north of the Columbia River.

Photo 1 Picture shows drill rig at the Anderson 11-5 well site in the spring 2006 prior to being moved to current Brown 7-24 well location.

Figure 14



Oil and Gas Operations Eastern Washington
Brown 7-24
Yakima Training Center
Anderville Farms #1-6
Hanford Reach
National Monument
Selah
Yakima
Moxee
Hanford Works
Anderson 11-5
Wapato
Zillah
Toppenish
Granger
Sunnyside
Richland
West Richland
Yakama Reservation
Grandview
Prosser
Gray 31-23
McBride 28-13
Columbia River
Well Sites
BLM Land
BLM Withdrawal
Indian Reservation
Bureau of Reclamation
U.S. Fish and Wildlife Service
Other Federal
WA State Parks and Recreation
WA Dept. of Fish and Wildlife
WA Dept. of Natural Resources
Cities
0 5 10 20 Miles
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Seattle
Wenatchee
Spokane
Map Area
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***Following are excerpts from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p**. Specific Site descriptions include Site 39 (Jericho Coulee - pages 87-88), Site 40 (Lower Crab Creek Coulee-pages 88-89), Site 41 (Beverly Bar – pages 90-91), and Site 42 (Sentinel Gap - pages 91-92).

Sentinel Gap*

Sentinel Gap is a water gap the Columbia River cut through the west end of the Saddle Mountains. The river became entrenched and has flowed through this gap for the last 13 to 14 million years. Once established, the river maintained a channel here, cutting down into the Saddle Mountains as they slowly arched upward over the eons. The distinct white band visible part way up the west wall of Sentinel Gap is called the vantage interbed (Ellensburg Formation), a sedimentary layer deposited between eruptions of Columbia River basalt about 15.6 million years ago.

During Ice Age flooding, Sentinel Gap was one of four major routes for floodwaters entering the Pasco Basin. When the Okanogan ice lobe was in place, Scabland floods passed through the gap after spilling over the Quincy cataracts (Crater, Potholes and Frenchman coulees), as well as down Lower Crab Creek Coulee. When the Okanogan lobe was absent, the Columbia flood(s) would flow directly down from the north. Together these floods probably widened and steepened the walls of Sentinel Gap. After passing through Sentinel Gap, floodwaters expanded and decelerated, depositing much of their sediment load, including basalt boulders up to 8 feet in diameter.

Beverly Bar*

Beverly Bar is a longitudinal flood bar that parallels the east side of the Columbia River. The last Ice Age flood coming down the Columbia Valley formed this bar. The bar built up across the mouth of Lower Crab Creek Coulee and therefore must be younger that the last Scabland flood coming down this coulee from the east. If a Scabland flood had occurred after the flood that formed Beverly Bar, the bar surely would have been destroyed by such a flood coming down Lower Crab Creek Coulee.

The tallest part of Beverly Bar is 125 feet at its north end and gently slopes southward. Silt deposits blanket older coarse-grained flood deposits in the lower Crab Creek, indicating that area behind the bar was a quiet-water area during the last flood(s) that back-flooded that valley from the west. Lower Crab Creek has since cut a narrow 40-foot-deep ravine across the southern end of Beverly Bar.

Lower Crab Creek Coulee*

Lower Crab Creek drains the Othello Basin, which divides the Frenchman Hills and the Saddle Mountains. Notice that, unlike in the Quincy Basin, no steep, receding cataract canyons exist here where Lower Crab Creek joins the Columbia River. This is because Crab Creek and periodically the Columbia River during the Ice Age, have occupied the valley during and since Ice Age times. As a result, Lower Crab Creek valley descends gradually along its length, ultimately joining the river just north of Sentinel Gap. Instead of steep cataracts like those at Potholes and Frenchman coulees, a single, underfit stream exists. The stream is flanked by some remarkable scabland stretching all the way up the valley to Drumheller Channels.

Scabland floods alone scoured out Lower Crab Creek Coulee. As they rushed to Sentinel Gap, they scoured and stripped clean the steep north side of the Saddle Mountains, especially at the far west end. Lower Crab Creek currently is occupied by a ridiculously small stream, compared to the size to the coulee it occupies.

Between Scabland floods, when the Okanogan ice lobe blocked the Columbia River and formed Glacial Lake Columbia, the river was diverted through Lower Crab Creek Coulee. It wasn't until later, after this lobe retreated, that the Columbia stopped flowing through Grand Coulee. At that time, the river returned to its current path through the Okanogan highlands and south through Wenatchee.

Jericho Coulee*

Jericho Coulee (Figure 15), similar to Red Rock Coulee/Natural Corral, is another lateral canyon carved into the Royal Slope that runs semi-parallel to Lower Crab Creek Coulee. Jericho Coulee makes a 4.5-mile detour across Royal Slope along the north side of the Lower Crab Creek Valley. The upper (east) end of this coulee hangs 300 feet above the main floor of Crab Creek. Bretz's critics argued that these lateral canyons represented not flood features, but area where meltwater from lazy glacial streams were forced to flow around ice jams. Bretz argued that in this area not a single ice-rafted erratic occurs; erratics should be present if an ice jam once existed here.

Like Red Rock Coulee/Natural Corral, Jericho Coulee may have developed as a result of the enlargement of a river channel that occupied the valley before Ice Age flooding. At least one remnant of eroded Ringold Formation sediment (Figure 15), which at one time partially filled Lower Crab Creek, is preserved as a stream-lined hill a couple miles east of Jericho Coulee. The Ice Age floods have stripped away most Ringold Formation sediment from this area.

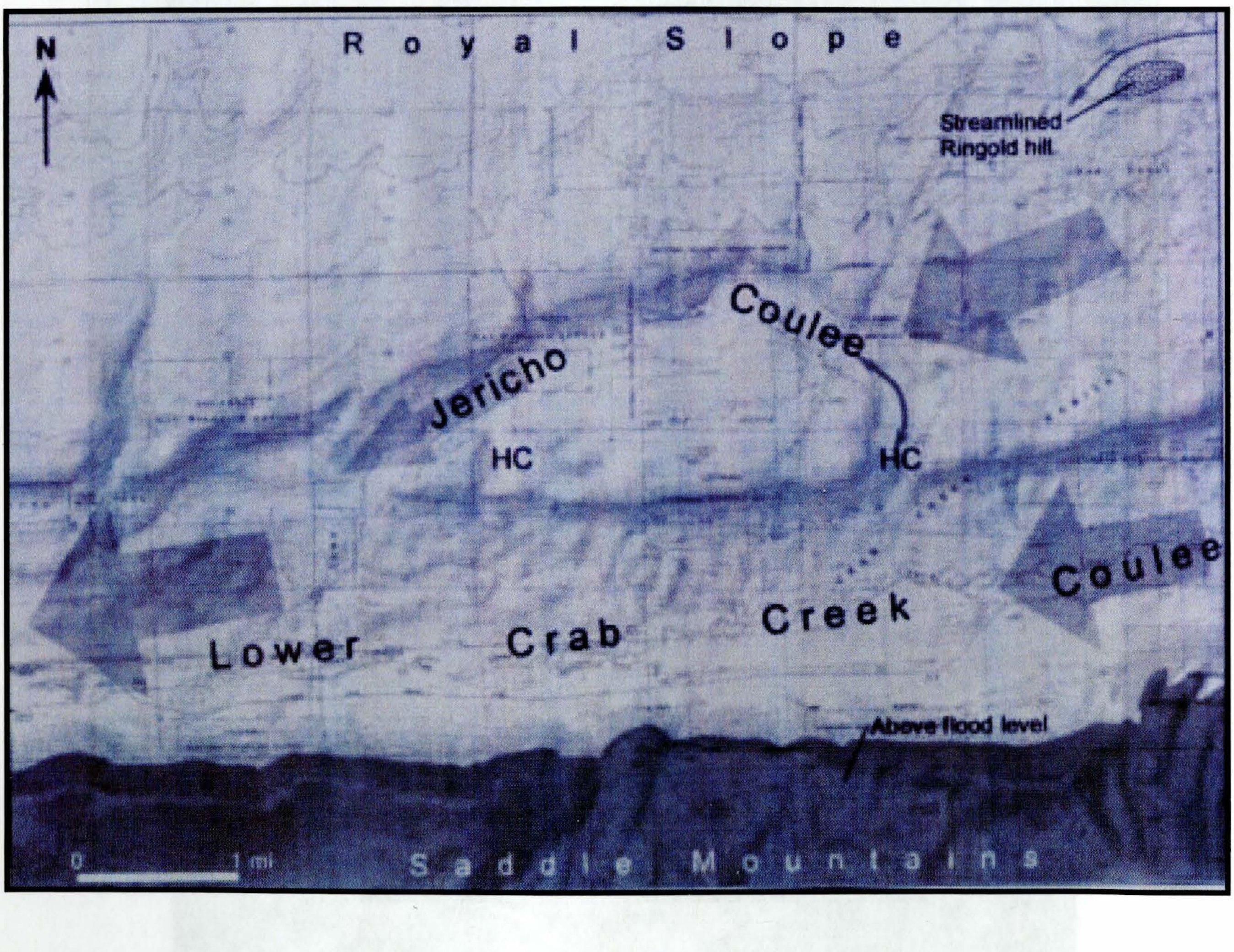

Figure 15 From *On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, Guide to the Mid-Columbia Basin. Figure 4-18, Page 88

Red Rock Coulee/Natural Corral

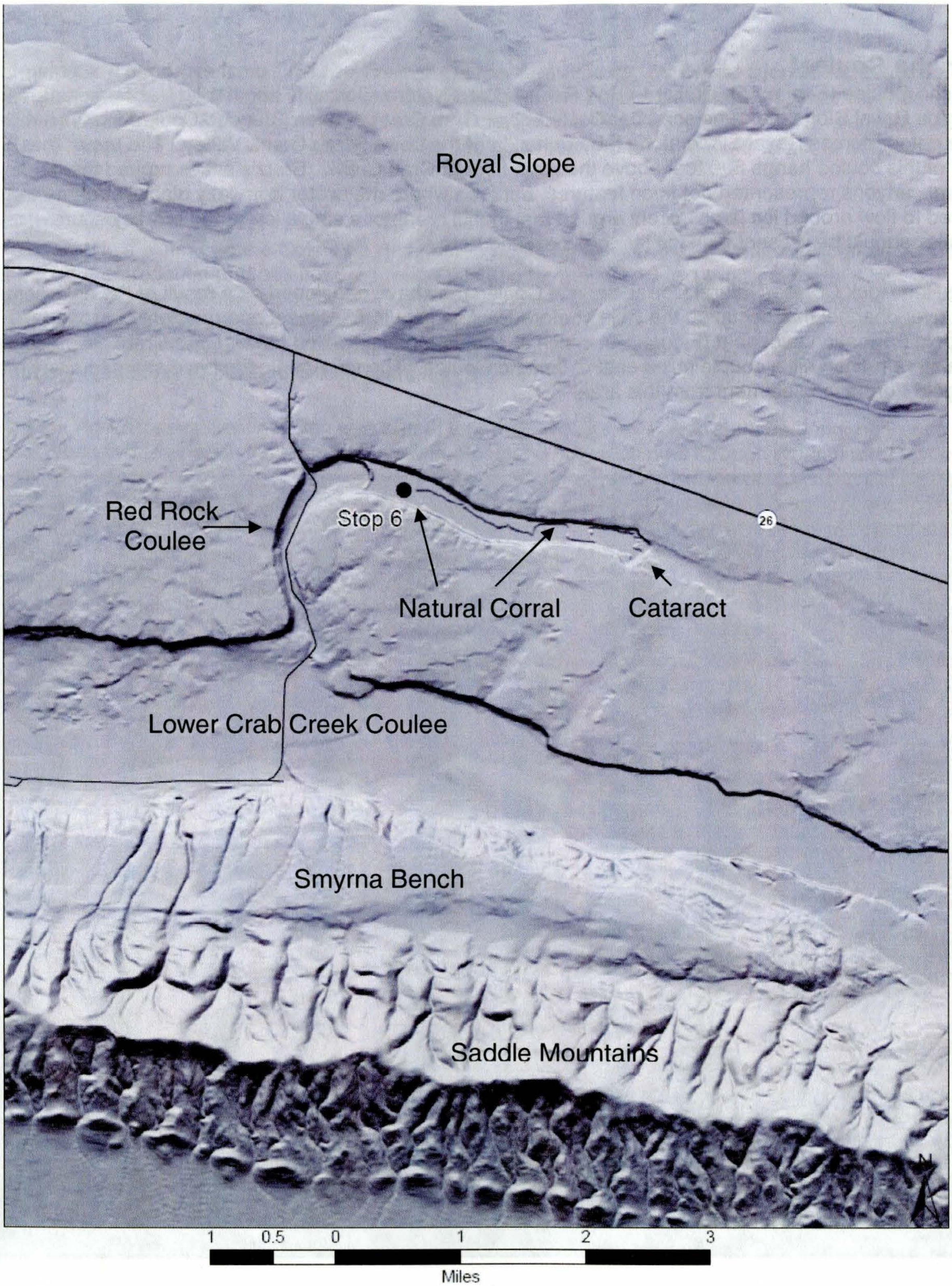

Figure 16 - Digital Elevation Model – Red Rock Coulee & Natural Corral

Image shows Saddle Mountains (bottom), Lower Crab Creek Coulee (north of Saddle Mountains) and Red Rock Coulee/Natural Corral.

STOP 6 – Red Rock Coulee and Natural Corral

Red Rock Coulee/Natural Corral (Figure 16) lies in a flood channel eroded into the Royal Slope, a broad, gentle, south-sloping surface underlain by mostly basalt. Four-mile-long Red Rock Coulee/Natural Corral carried floodwaters out of Drumheller Channels and into Lower Crab Creek Coulee. Natural Corral is a steep-walled, lake-filled coulee with a 100-foot-tall, dry, recessional cataract canyon that completely encloses the coulee on three sides. From Drumheller Channels, Natural Corral heads straight west, then bends 90 degrees to the south, becoming Red Rock Coulee. Sharp bends like this normally are not seen in flood channels: Ice Age floods tend to carve straight to broadly curving channels. So this sharp-bending coulee probably represents the path of a former river channel, what geologists call a cut-off meander that likely formed before the Ice Age floods began. Later, the floods naturally followed the path of least resistance, which was down this old river channel, modifying it somewhat. This bent coulee is similar to nearby Jericho Coulee, which probably has a similar origin.

Two well-developed flood bar – composed of basalt-rich, stratified sand and gravel – collected along the inside of the bend as some of the floodwater whipped around from Natural Corral into Red Rock Coulee. The upper flood bar, a type of pendant-crescent bar, is higher (about 160 feet) along the north side of the bend. A lower flood bar is found near the mouth of Red Rock Coulee. The top of the lower bar is strongly weathered and, therefore, probably formed during an older flood.

Excerpt from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p. Specifically Site 38 entitled Red Rock Coulee/Natural Corral (page 86).

Figure 17 - Image from Google Earth showing Natural Corral (center) and Red Rock Coulee (right). View is southeast.

Corfu Landslide Complex

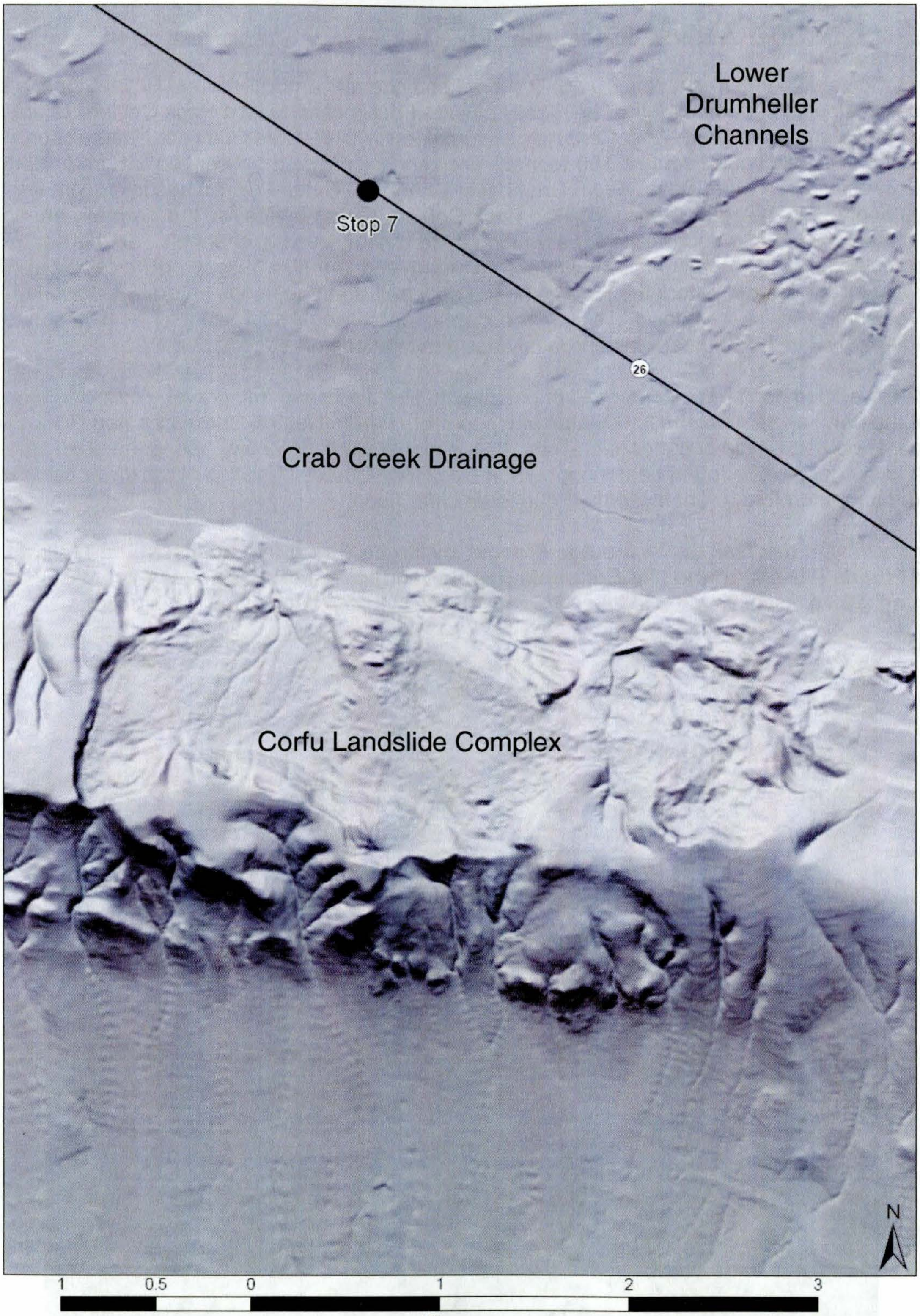

Figure 18 - Digital Elevation Model – Corfu Landslide Complex

Image shows the Corfu Landslide Complex located in the eastern portion of the Saddle Mountains. Lower Drumheller Channels are in the upper right of image.

STOP 7 – Corfu Landslide Complex

***The following are excerpts from "*On the Trail of the Ice-Age Floods*" by Bruce Bjornstad, 2006, On the Trail of the Ice-Age Floods – Guide to the Mid-Columbia Basin: Sandpoint, Idaho: Keokee Company Publishing, 296 p**. Specifically Site 37 entitled Corfu Landslide Complex (pages 85-86), Site 24 entitled Parting of the Waters (page 69), and Site 22 Othello Channels (pages 67-68).

The Corfu Landslide Complex (Figure 18), which consists of at lease 24 separate sliding events, covers 7 to 8 square miles. Scabland floods that eroded Lower Crab Creek probably undercut the steep north-facing slopes on the Saddle Mountains, which caused the mountainside to slump. Earthquakes that accompanied Ice Age floods may have triggered many of the landslides. Even though floodwaters reached only about halfway up the side of the Saddle Mountains, landslides extended all the way to the crest of the ridge. At least some sliding occurred prior to the last Scabland flood. Geologists know this since older landslide debris was eroded and smoothed by younger, Scabland floods. Some landsliding occurred after the last Scabland flood too, however. This is indicated by several landslide-generated debris flows that ran into Lower Crab Creek Coulee. Any flood coming down Crab Creek after these lobes of debris formed would surely have eroded away this material along the bottom of the coulee. Some post-flood slides may have occurred after high-precipitation and/or seismic events, not necessarily related to Ice Age floods.

You can view the landslide complex from a number of places along Lower Crab Creek, but perhaps the most spectacular view is looking down onto the landslide from where it started near the crest of the Saddle Mountains. From here one can look directly down the throat of a steep head scarp from the Saddle Mountains Overlook.

Parting of the Waters*

A major divergence in the floodwaters, referred to here as "Parting of the Waters," occurred near Othello toward the eastern end of the Saddle Mountains. Here, floodwaters rushing down from Drumheller Channels smashed head on into the Saddle Mountains. The ridge was too high for floodwaters to flow over, so they were forced to flow in opposite directions along the north side of the impasse. Some floodwaters poured west down lower Crab Creek Coulee toward an opening in the Saddle Mountains at Sentinel Gap. The remainder rushed east around the nose of the Saddle Mountains where the ridge finally lowered enough for floodwater to spill over at Othello Channels.

The point of flow divergence is represented by the apex of a triangle-shaped raised point of land that juts northward from the Saddle Mountains. This wedge of land is almost flat on top and lies 300 feet above lower Crab Creek Valley. The wedge represents an erosional remnant of the Ringold Formation, which once partly filled the Othello Basin. Ringold Formation sediments were preserved because floodwaters moved slightly slower here. On either side of the wedge, erosive floodwaters completely stripped away the Ringold sediments. Huge rounded basalt boulders up to 4 feet in diameter, ripped out of Drumheller Channels, litter the upper surface of the wedge.

Othello Channels*

The Othello Channels were the conduit for floodwaters that were herded to the southeast by the Saddle Mountains, after escaping through Drumheller Channels. They in turn transported floodwater into the Pasco Basin via Ringold and Koontz coulees. The Othello Channels consist of two flood coulees – Eagle Lakes on the west and Scooteney Reservoir to the east. An eroded basalt ridge, partially covered by a streamlined remnant of the Ringold Formation, separates the two Othello Channels. The channels bend around the Saddle Mountains where floodwaters spilled over the crest of the basalt ridge at its east end. Deep scabland channels developed where floodwaters cut across the ridge. Eagle Lakes and Scooteney Reservoir contain deep rock basins, plucked out of basalt bedrock, that are up to 135 feet deep. North and south of the eroded nose of the Saddle Mountains, where floods cut into the "softer," more easily eroded sediments of the Ringold Formation; the channels are much more subdued.

Drumheller Channels/Jackass Mountain

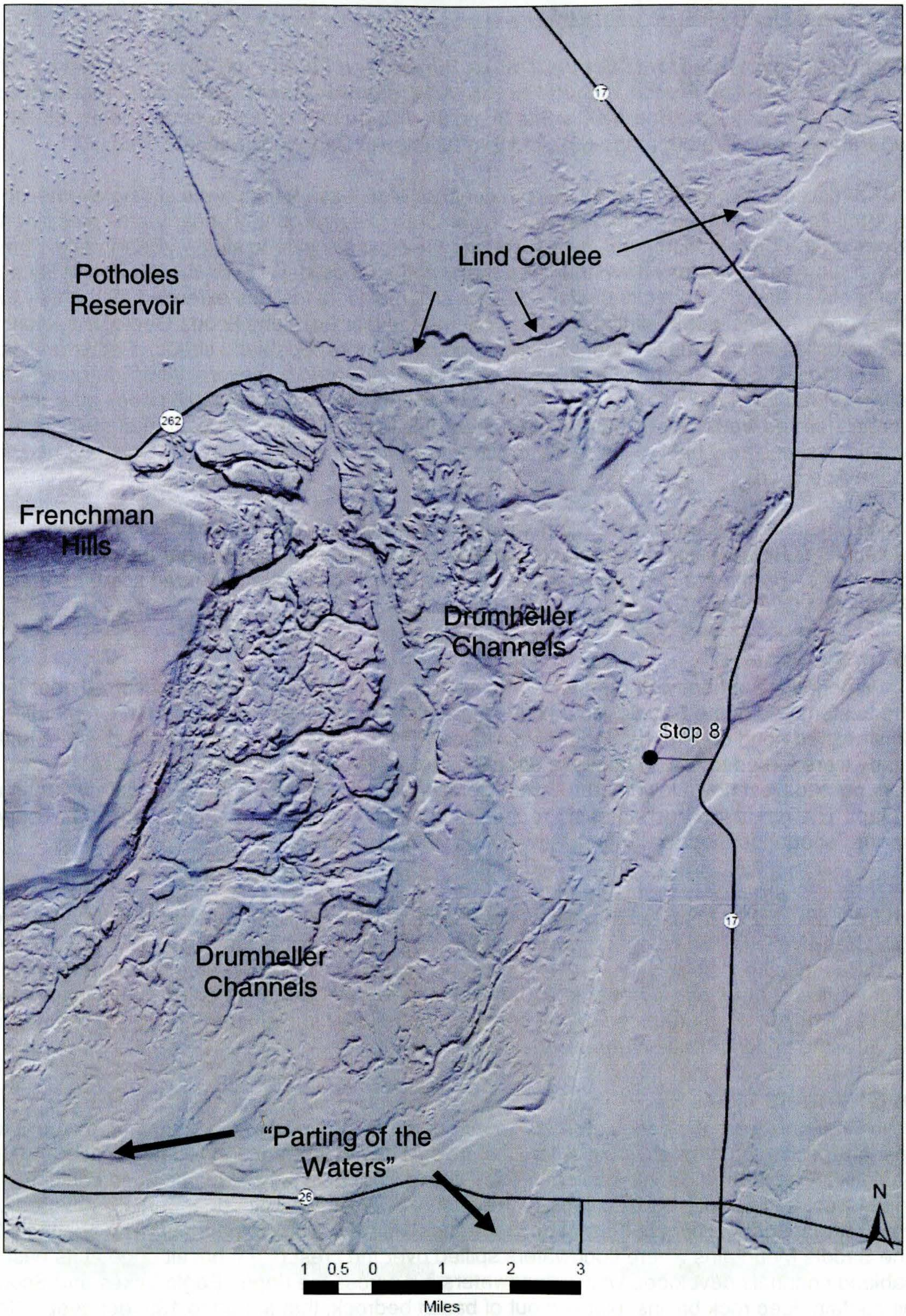

Figure 19 - Digital Elevation Model – Drumheller Channels/Jackass Mountain

Image shows the extent of the Drumheller Channels, Lind Coulee, Potholes Reservoir and Jackass Mountain (Stop 8 at south end).

STOP 8 – Drumheller Channels and Jackass Mountain

Drumheller Channels

The following is an excerpt from Bretz (1959) describing the Drumheller Channels.

> As to the Drumheller Channels Bretz writes:
>
> *"This enormous spillway, Drumheller Channels… in the extreme southeastern corner of the Basin…" (Referencing Quincy Basin) "…was deepened more rapidly than the western channels and eventually captured all their share of the flood water."*
>
> *"Its deepening continued through successive floods until it had been cut 300 feet into a previously intact divide. Drumheller is the most spectacular tract of butte-and-basin scabland on the plateau. It is an almost unbelievable labyrinth of anatomizing channels, rock basins, and small abandoned cataracts. Only one channel in the plexus, the route now followed by Crab Creek, has a continuous gradient across Drumheller's 50-square-mile area; and this route almost surely has rock basins leveled up by the creek's sand and gravel in postglacial time. The average descent across the tract is between 30 and 50 feet per mile. Drumheller was a gigantic cascade rather than a unit waterfall, because the basalt beneath had been flexed, broken, and faulted in one of the plateau's strongly accented upfolds, the Frenchman Hills anticline. Although higher and earlier rock-bound channels were abandoned as the deepening progressed, no marked central channel and no dominant cataract developed."*

Bretz was referring to the three other outlets along the western edge of the Quincy Basin; they are from north to south: Crater, Potholes, and Frenchman Springs Coulees.

Jackass Mountain

The sediments located here at Stop 8 represent an erosional stream-lined remnant of Ringold Formation overlain by Ice Age flood(s) coarse gravel deposit capped by loess. Much of the upper portion of the outcrop is well cemented with caliche therefore indicating that these gravels represent older Ice Age floods gravel deposit pre-dating the most recent (13,000 to 15,000) episode of Ice Age catastrophic flooding. This sediment sequence as illustrated and described by Reidel and others (1992) make reference to the upper portion of the Ringold Formation - member of Savage Island unconformably overlain by younger Cold Creek Unit of the Hanford Formation (Figure 20).

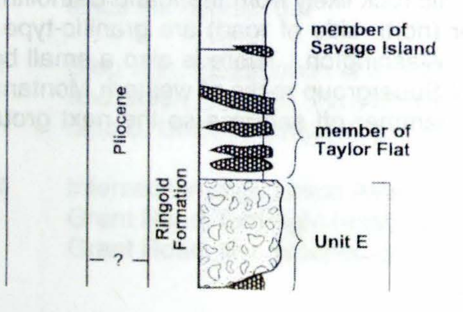

Figure 20 – General stratigraphy post-Columbia River Basalt Group sediments in the Pasco Basin (from Reidel and others 1992). Figure only shows upper portion of stratigraphic column (upper Ringold Formation and younger). The outcrop at Jackass Mountain may be represented on the stratigraphic column by the boundary between the underlying Ringold Formation (member of Savage Island) and Cold Creek Unit of the Hanford Formation.

Ice-Rafted Erratics – Frenchman Hills

Photo 2 – Ice-Rafted Erratics along State Highway 262

STOP 9 – Frenchman Hills – Ice Rafted Erratics

Please be very careful crossing the highway!!!!

There are several different types of ice-rafted erratics or rocks that were transported to this area encapsulated in icebergs. They were stranded up on the hillside of the Frenchman Hills (north side) when flood waters receded in the Quincy Basin. It is likely that all of these rocks have been removed from adjacent agricultural fields and are no longer in place (although there are several large boulders to the NW in a field that appear to be still in place). The largest boulder (4 ft diameter) is now in several large pieces and is a very coarse grained or "pegmatitic" granitic rock likely from the Idaho Batholith. One larger rock on the south side of SR-262 and several smaller (north side of road) are granitic-type rocks (diorite/granodiorite) likely from an area north of Wenatchee, Washington. There is also a small boulder of argillite (metamorphosed siltstone) associated with the Belt Supergroup rocks of western Montana (this rock type dominates Glacier National Park). Please do not hammer off samples so the next group can enjoy this stop. Return to the vehicle.

Watch for Traffic!

ROAD LOG - MILEAGE OF STOPS

Start Inn at the River (580 Valley Mall Parkway) – Lodging/Registration /Meeting Place

0.0 Exit parking lot (right) onto Valley Mall Parkway get into left lane. 0.2

0.2 Intersection of Grant Road and Valley Mall Parkway, turn left (east) onto Grant Road. 0.1

0.3 For the next mile many boulders 1.5 to 6 ft in diameter have been cast away beside commercial developments, used for retaining walls, and/or landscaping. **1.7**

2.0 The topographic waves sliced by successive roadcuts are giant current dunes. Grant Road east ascends the foreslope of perhaps the world's most colossal crescent bar "Pangborn Bar". Many boulders are as large as 1.5 ft. Decorating this surface are loess-mantled giant current dunes. Large parabolic dunes embellish the backslopes of giant transverse dunes. Some roadcuts show that mixed-lithology pebble gravel composes the duneforms beneath about 6 inches of loess. **1.2**

3.2 Turn right (south) onto S. Roland Avenue. **0.2**

3.4 At "T" intersection (stop sign), turn left (east) onto 2nd Street. **0.2**

3.6 **Stop 0.1 (rolling)** Giant current dunes. Dune crests are spaced about 550 ft. The top of this bar is 700 ft. above the Columbia River, which has not significantly downcut since the floods. 0.5

4.1 Stop sign. Intersection of 2nd St. and Union Avenue. Turn left (north) onto S. Union Avenue. 0.3

4.4 Intersection of S. Union Avenue and Grant Road, turn right (east) onto Grant Road, and proceed east. 0.3

4.7 Pangborn Airport on right (south). 0.3

5.0 **Stop 0.2** (rolling) Clovis Archaeological site. Richey Clovis Cache – Archaeological site that contained numerous "Clovis" people spearheads and other artifacts. Site (right) was discovered in 1987 and is now covered with concrete for protection (not visible). 0.6

5.6 At curve past airport turn left onto Grant Road. 0.1

5.7 **Stop 0.3** (rolling) Ice-Rafted Erratics (granite) located several hundred feet above lower Pangborn Bar-north on hillside. 0.4

6.1 Intersection of Grant Road and South Ward Avenue. Turn right (south) onto S. Ward Ave. 0.6

6.7 Intersection of S. Ward Ave. and 4th St. Turn left (east) onto 4th St. 0.5

7.2 Webb Ave. Erratic to north (left) at top of hill above landfill. 1.3

4th St. becomes Batterman Road

8.5 Basalt borrow site on left. 0.7

9.2 Jump Off Joe Ridge and Malaga Slide are located to the southwest and west respectively. The Moses Coulee giant gravel bar can be seen to the southeast and Columbia River Basalt (flows) is visible to east which are part of the Grande Ronde Member (15.5-17.5 million years old). 1.0

10.2 Intersection of Batterman and Saunders Roads. 0.1

10.3 Rhythmites on left. 0.7

11.0 Intersection of Batterman Road and SR-28. Turn left onto SR-28. 0.8

11.8 Large – very long basalt colonnades (columns) or commonly referred to as columnar jointing in cliff faces to left (north) are part of the

"Hammond Sill". Pillow basalts are also visible closer to road. 0.6

12.4 **Stop 0.4** (rolling) Rhythmites west of Rock Island Dam (across river). 0.6

13.0 Rock Island Dam (south), the first built on the Columbia River (1931). 0.9

13.9 Start the climb up onto Moses Coulee Bar. 0.2

14.1 Rhythmites on left – temporary lake impounded by blockage of Columbia River drainage by Moses Coulee Bar south of Rock Island. Rhythmites are layers that formed as sediments settled out of the impounded lake. 0.4

14.5 For the next mile small hills in road cuts are large current dunes on Moses Coulee Bar. Several dunes are cut by road excavation into WADOT weight station. 1.9

16.4 Intersection of Palisades Road and SR-28, turn right onto frontage road. 0.7

17.1 Proceed south on Nelson Siding (frontage) Road until wide pull-off.

STOP 1 – Moses Coulee and Moses Coulee Bar 0.1

17.2 Junction of Nelson siding Road and CRO Drive turn left. Turn right back onto SR-28 (south) 0.6

17.8 Cross Douglas Creek Drainage. 2.7

For next several miles good examples of basalt profiles, note pillow-palagonite, entablature and colonnade.

20.5 Pillow-palagonite with "foreset bedding" (left) dipping north. 0.8

21.3 Basalt column mining on left. 1.0

22.3 View of West Bar and Babcock Bench to south (right). 0.9

23.2 SR-28 cuts through sand deposit, which is the remnant of a large counter-clockwise eddy. Note foreset bedding in sand dipping toward river. 1.0

24.2 Railroad overpass. 0.2

24.4 Intersection of SR-28 and Crescent Bar Road. Turn right onto Crescent Bar Road. 0.1

24.5 Intersection of Crescent Bar and W.8 Roads. Turn left onto W.8 Road. 0.2

24.7 Intersection of W.8 and NW 9.8 Roads. 0.1

STOP 2 – West Bar and Babcock Bench Overlook

NOTE: Ken & Susan Lacy (homeowners) have graciously allowed us to use their front yard as a view point for this stop. Please stay on grass and do not trample flower beds! Thank You!

24.8 Intersection of NW 9.8 Road and unnamed gravel road, turn right onto gravel road. 0.1

24.9 Intersection of unnamed gravel road and Crescent Bar Road, turn right onto Crescent Bar Road. Trinidad Store on right. 0.2

25.1 Intersection of Crescent Bar Road and SR-28, turn right (east) onto SR-28. 0.4

25.5 Cross Lynch Coulee. 0.5

30.0 Baked soil horizon between two basalt flows (red coloration). 0.6

30.6 Columns and entablature on left. 1.3

31.9 Rest Stop on right. 0.6

32.5 Intersection of SR-28 and White Trail Road, turn right onto White Trail Road. 3.9

36.4 Wild Horse Wind Farm visible to the southwest. Average dimensions of the towers and blades are as follows, hub height (150'-260'), tip height (250'-410') and rotor diameter (200'-295'). 1.0

37.4 Potholes Coulee visible to south. 1.0

38.4 Quincy Lakes access road. Turn right onto gravel road. 0.5

33.9 Enter Quincy Lakes Wildlife Recreation Area. 0.3

34.2 Parking lot on right is upper access to Ancient Lakes (plunge pool) for the northern half of Potholes Coulee. 0.1

34.3 Large basalt columns – Roza member. 0.1

34.4 Stan Coffin Lake (left). 0.4

34.8 **Rolling Stop 2.1** Pillow-palagonite and diatomaceous earth outcrop. 0.3

35.1 Quincy Lake (left). 0.4

35.5 Burke Lake (left) 0.1

35.6 Dusty Lake Trailhead. 0.2

35.8 Evergreen Reservoir cross one-lane road on dike. 0.4

36.2 Pull-off by restroom.

STOP 3 – Potholes Coulee Overlook

Recessional Cataract
We will be walking a short distance to the top of a "cliff" that overlooks upper Potholes Coulee and Dusty Lake "plunge pool". Please use extreme caution!!!! 0.5

36.7 Quincy Lake WRA south gate. 0.1.

36.8 Bureau of Rec. pumping station (left). 0.4

37.2 Vineyards. 0.1

37.3 Irrigation surge tower. 0.2

37.5 Road veers left (east) into Road 2 NW. 0.2

37.7 Intersection of 2 NW and U NW Roads. Turn right (south) onto U NW Road (pavement begins). 1.0

38.7 Stop sign. Turn right onto Road 1 NW. 2.0

40.7 Road 1 NW curves 90° south and becomes W NW Road. 0.4

41.1 The Gorge Amphitheater. 0.3

41.4 Cave B Winery. 0.3

41.7 Intersection of W NW & and Baseline W Roads. Continue south (straight), road becomes Silica Road. 1.1

42.8 Road right to Sunland Estates. 2.0

44.8 Diatomaceous earth open pit mine located both N & S of Silica Road. 0.7

45.5 View of Frenchman Coulee to south. 0.4

45.9 Intersection of Silica Road and Old Vantage Highway. Turn right onto Vantage Road. 0.4

46.3 Start into Frenchman Coulee – North Alcove. 0.2

46.5 Note large basalt columns on right. Roza Member. 0.7

47.2 Rolling Stop 3.1. One row of basalt columns separates two alcoves named the "Feathers". 0.6

47.8 Note entablature on north wall of coulee. 0.7

48.5 Entablature boulders eroded out are located at base of coulee wall. 0.2

48.7 Frenchman Coulee – South Alcove. 0.5

49.2 Gravel bar studded with large basalt entablature "lag" boulders. 0.2

49.4 Start transcending down through enormous gravel bar below Frenchman Coulee. 1.0

50.4 Turn around at boat launch. **Rolling Stop 3.2**. Note gravel bar to north, Sentinel Gap in the southern distance and the basalt stratigraphy across the Columbia River. 1.4

51.8 Pull-off on right. **STOP 4 – Frenchman Coulee Recessional Cataract** View into Echo Basin (South Alcove), Babcock Bench to north and recent sand dunes. 3.2

55.0 Intersection of Vantage and Silica Roads, turn right (south) onto Silica Road. 0.6

55.6 Turn right on I-90 on ramp. 1.2

56.8 Frenchman Hills on south (left). 0.5

57.3 Fosse or flood eroded channel (right). 1.3

58.6 Babcock Bench. 1.1

59.7 Wild Horse Monument Rest Area (right). 2.4

62.1 Bridge over Columbia River. 1.1

63.2 Take Exit 136 I-90 off-ramp. 0.3

63.5 Turn left at off-ramp stop sign and follow signs to Ginkgo Petrified Forest State Park. 0.6

64.1 Turn right onto Gingko Avenue. 0.2

64.3 Gingko Rock Shop on right. 0.3.

64.6 Enter Gingko Petrified Forest State Park and pull around to bus/RV parking area. 0.1

64.7 STOP 5 - Gingko Petrified Forest State Park 0.1

64.8 Leave Gingko Petrified Forest State Park. 0.4

65.2 Intersection of Gingko Road and Old Vantage Highway, turn left onto Old Vantage Hwy. 0.7

65.9 Right onto I-90 E on-ramp and proceed east on I-90. 1.3

67.2 Columbia River 1.1

68.3 Take Exit 137 off I-90 (SR-26 and SR-243). 0.3

68.6 Sand Hollow Member (CRBG) on left (east) showing entablature. 0.7

69.3 Intersection of SR-26 & SR-243 continue straight (east) on SR-26. 0.3

69.6 **Rolling Stop 5.1** Excellent pillow-palagonite sequence in roadcut to left (north) Sand Hollow Member (CRBG). 4.7

74.3 Frenchman Hills visible to the north (left). 0.9

75.2 Intersection of SR-26 and Beverly Burke Road. Turn right (south) onto Beverly Burke Road. 2.0

77.2 Beverly Burke Road turns 90º to west. 0.5

77.7 Schist boulder erratic on left fence row. 1.0

78.7 **Rolling Stop 5.2** Access road (left-south) to EnCana's Brown 7-24 Natural Gas Exploration Well. 0.6

79.3 Sentinel Gap (Columbia River passes through Saddle Mtns.). 1.0

80.3 Beverly Burke Road turns to SW. 1.2

81.5 Wanapum Dam visible to NE. 1.1

82.6 Intersection of Beverly Burke Road and SR-243. Turn left (south) onto SR-243. 0.6

83.2 Old CMS&P RR Bridge. 0.2

83.4 Intersection of SR-243 and Lower Crab Creek Road. Turn left (east) onto Lower Crab Creek Road. 0.3

83.7 Numerous basalt bedload boulders. 0.9

84.6 Basalt scablands on left (north). 0.8

85.4 Beverly Dunes (right) off road park. 1.1

Traveling along the north side of the Saddle Mountains a large anticline (fold) with a gentle south slope (Wahluke Slope) and thrust faulted northern slope (limb). The thrust fault parallels along Lower Crab Creek Road.

86.5 Pavement ends. 1.8

88.3 Parking lot (left) is access to Lenice Lake. 0.8

89.1 Cross Crab Creek. 0.9

90.0 Basalt scablands on left (north). 3.5

93.5 Large gravel bar in distance within connecting coulee along north wall of Lower Crab Creek drainage. 2.9

96.4 Blacktop begins (Smyrna, WA). 0.2

96.6 Old Smyrna School on right (south). 0.8

97.4 Cross old CMS&P RR bed (WA State Parks). 2.0

99.4 Road turns north and becomes Road E SW (Red Rock Coulee). 0.1

99.5 Railroad trestle on right (east). 0.1

99.6 Cross Crab Creek. 0.9

100.5 Gravel pit on right (east) is a pendant bar off north wall of coulee. Sediments show cross-bedding and Mt. Mazama Ash layer towards top. Proceeding north up into Red Rock Coulee. 0.4

100.9 Gravel pit on right (east) partially reclaimed. 1.0

101.9 Turn right (east) onto gravel road with access to Natural Corral. 0.2

102.1 Cross old RR tracks and stay left (paralleling RR tracks). 0.7

102.8 Turn-around at lake filling Natural Corral.

STOP 6 – Red Rock Coulee and Natural Corral

Return to Red Rock Coulee (Road E SW). 0.9

103.7 Intersection of Natural Corral access road and Road E SW. Turn right (north) onto Road E SW. 0.4

104.1 Large colonnade in roadcuts. 0.2

104.3 Flood gravel bar deposit on right (east). 0.3

104.6 Cross RR tracks. 0.3

104.9 Intersection of Road E SW and SR-26. Turn right (east) onto SR-26. 1.3

106.2 Smyrna Bench to the south (right). 0.7

106.9 Dodson Road intersection. 1.3

108.2 Wahatis Peak (south) high point in the eastern Saddle Mtns. 2.9

111.1 Junction SR-262 1.4

112.5 Large pullout on south side of SR-26 (Just past Road B SW).

STOP 7 – Corfu Landslide Complex 2.9

115.4 Basalt scabland. 1.0

116.4 Excellent view of Corfu Landslide on right (south). 0.7

117.1 Cross Crab Creek. 0.8

117.9 Ringold Formation sediments visible on right (south) for next couple of miles. Remnant of Ringold Fm. Know as "Parting of Waters". 3.0

120.9 Vast "Channeled Scabland" to north is southern portion of Drumheller Channels entering lower portion of Lower Crab Creek. 2.0

122.9 "Parting of Waters" diversion of floodwater around east end of Saddle Mountains (Lower Crab Creek – west & Othello Channels – south). 1.0

123.9 Concentration of bedload boulders (predominately basalt). 1.8

125.7 Cross Potholes Canal. 0.7

126.4 Turn left into Othello (1st Avenue). 1.0

127.4 Intersection of 1st Avenue and Main Street, turn right (east) onto Main Street. 0.2

127.6 Othello City Park – Break and Bathroom Stop. 0.3

127.9 Continue east on Main Street Columbia National Wildlife Refuge and Bur. of Rec. Office on left (north). 1.5

129.4 Intersection of Main Street (Cunningham Road) and SR-17, turn left (north) onto SR-17. 5.2

134.6 Intersection of SR-17 and Road 12 SE (Providence Road), turn left (west) onto Road 12 SE. 0.7

135.3 Intersection of Road 12 SE and Reynolds Road, continue straight and turn left onto driveway in several hundred feet and head to south end of Jackass Mountain. 0.3

135.6 STOP 8 – Jackass Mountain

– Jackass Mountain - Ringold Formation, Floodwater gravel deposits, caliche and Mt. St, Helens Ash layer. 0.3

135.9 Intersection of Reynolds and Providence Roads. 0.6

136.5 Gravel pit to north and loess in road cut capped by Mt. St, Helens Ash layer. 0.1

136.6 Intersection of Road 12 SE and SR-17, turn left (north) on SR-17. 3.0

139.6 Warden Jct. (SR-170) continue north on SR-17. 1.0

140.6 Intersection of SR-17 and SR-262, turn left (west) onto SR-262. 2.1

142.7 Public access to Warden Lake. 0.4

143.1 Ringold sediments visible to north (right) in Lind Coulee. 1.6

144.7 Road M SE 2.3

147.0 Intersection of Morgan Lake road and SR-262, continue west (straight) on SR-262. For the next three miles view (south) the western third and deepest portion of the Drumheller Channels. 0.5

147.5 Crab Creek to south, Potholes reservoir to the north side of O'Sullivan Dam. 0.9

Some of the higher basalt buttes to the south of O'Sullivan Dam have been mapped by Grolier and Bingham (1971) as the Priest Rapids Member-Wanapum Basalt.

148.4 Note off in the distance to the north-northeast (north of Potholes Reservoir) the tall bank of gravel. Large accumulation of sand and gravel that settled out in the Quincy Basin when flood waters ponded for a short before being funneled back into the Drumheller Channels. 2.1

150.5 West end of O'Sullivan Dam Road – Mardon Resort. Frenchman Hills off to the south (left) which funneled water to the east into the Drumheller Channels. 0.8

151.3 Intersection of O'Sullivan Dam Road (State Highway 262 or SR-262) and H-SE Road. Continue west (straight) on SR-262. 1.8

153.1 Caliche in roadcut on south (left). Caliche or sometimes referred to as "desert concrete" is formed in low rainfall or arid areas by the near surface crystallization of calcite and/or other soluble minerals by upward-moving solutions. Usually takes a long period of time to develop, sometimes tens of thousands of years. 0.1

153.2 Caliche in roadcut (south). 0.4

153.6 For the next several miles note the small hills in the distance to the north-northwest. These hills are sand dunes, some of which are still active, although many have stabilized since the raising of the water table in the Quincy Basin due to the influx of water related to the Columbia Basin Project. 3.9

157.5 Just before (east of) the junction of SR-262 and Frenchman Hills Road (Road 7 SW) turn left (south) into hay storage area. Vehicles can use this area as a turn-around.

<u>STOP 9</u> – Ice-Rafted Erratics along North Slope of Frenchman Hills. Please be very careful crossing the highway!!! 0.1

157.6 Intersection of SR-262 and Frenchman Hills Road (Road 7 SW), turn right (north) onto Frenchman Hills Road (Road 7 SW). 4.7

162.3 Intersection of Frenchman Hills Road (Road 7 SW) and Dodson Road, turn right (north) onto Dodson Road. 0.7

163.0 Cross Frenchman Hills Wasteway (irrigation drain). 3.2

166.2 Active sand dune (left). 2.2

168.2 Cross Winchester Wasteway (irrigation drain). 3.7

172.1 I-90 West freeway on-ramp, turn left onto on-ramp. 2.8

174.9 I-90 Rest Stop. 0.3

175.2 Cross Winchester Wasteway. 6.9

182.1 Adams Road. 2.6

184.7 I-90 Exit 151 (SR-281N). 0.3

185.0 Stop sign at end of off-ramp turn right. 0.1

185.1 SR-283 Intersection (stop sign) continue straight ahead. 1.5

186.6 SR-281 Intersection, turn right (north) onto SR-281. 3.0

189.6 White Trail Road 4.2

193.8 Enter Quincy 0.2

194.0 Cross USBR Irrigation Canal and stay in left lane. 0.5

194.5 Intersection of SR-281 & SR-28, turn left onto SR-28. 0.8

195.3 ConAgra Foods. Beezeley Hills to north. 1.2

196.5 Start decent into upper Crater Coulee. 1.1

197.6 Cross Crater Coulee. 1.0

198.6 White Trail Road. 0.6

199.2 Rest Area (left) 0.3

199.5 Start decent into Lynch Coulee. 0.9

200.4 Colonnade on right. 0.4

200.8 Lynch Coulee (right). 0.3

201.1 Soil horizon (left) 0.4

201.5 Cross Lynch Coulee. 0.5

202.0 Trinidad. 1.1

203.1 Sand deposit and West Bar (left). 1.7

204.8 Mining of basalt columns. 0.5

205.3 Pillow-palagonite sequence (north-right). 1.0

206.3 Colonnade with entablature above (right). 2.1

208.4 Douglas Creek-Moses Coulee. 0.3

208.7 Travel up onto upper Moses Coulee gravel bar. 1.1

209.8 Palisades Road (right) – access to Moses Coulee. 1.3

211.1 WADOT Truck Stop Scale. 0.4

211.5 Descend Moses Coulee gravel bar. 0.4

211.9 Rhythmite outcrop (right). 1.1

213.0 Rock Island Dam. 0.8

213. 8 Pangborn Bar visible ahead (west). 0.9

214.7 ALCOA on south (left). 1.4

216.1 Rock Island – American Silicon Technologies Smelter (closed down). 2.8

View of cantilevered Great Northern Railroad Bridge (1893), both ends anchored in preflood landslide blocks.

218.9 Malaga Landslide. 1.3

220.2 Rock Island Hydro Park on left. 2.4

222.6 Get into right turn lane. 0.1

222.7 Intersection of SR-28 & Grant Road, Turn right onto Grant Road. 0.1

222.8 Immediate left onto Valley Mall Parkway at next light. 0.2

223.0 Turn left into Inn at the River - Tour ends - Parking Lot

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List of Terms Utilized

Alcove – A deep, horseshoe-shaped inner canyon that forms below a recessional cataract.

Anticline – A fold that is convex upward.

Basalt - A dark, tough, fine-grained to dense, extrusive volcanic rock commonly occurring in sheet like lava flows.

Colonnade – That portion of a "lava flow" that displays linear columns (perpendicular to the cooling surface) or "columnar jointing". Most common in basalt (eastern WA) but can be common in other volcanic rocks. Common in Columbia River Basalt Group lava flows.

Cordilleran Ice Sheet – The name for the ice sheet, thousands of feet thick, that extended across western North America from the Canadian artic during the Pleistocene Epoch.

Coulee - Generally applied throughout the northern tier of the United States to any steep-sided gulch or water channel and at times even to a stream valley of considerable length.

Crescent Bar – A giant flood bar that forms around the inside bend or curve in flood channels.

Current Dune – A dune produced by the action of a current flowing steadily in one direction over a bed of sediments (sand and gravels). These "current dunes" have a long gentle slope toward the direction from which the current comes, and a shorter steeper slope on the "lee" or downstream side.

Entablature – That portion of a "lava flow" that displays radiating short hacky columns. Common in Columbia River Basalt Group lava flows.

Erratic - A transported rock fragment, usually transported by glacial ice (commonly icebergs), different from the bedrock on which it lies, either free or as part of sediment. The term is generally applied to fragments transported by glacier ice or by floating ice.

Foreset Beds – the series of inclined layers accumulated as sediment rolls down the steep frontal slope of a delta.

Gneiss – A coarse-grained metamorphic rock in which bands rich in granular minerals alternate with bands in which schistose mineral predominate.

Granite - A crystalline, plutonic rock, usually gray to pink in color, consisting essentially of alkali (potassium) feldspar and quartz, with smaller amounts of Muscovite, biotite, hornblende or pyroxene.

Loess - A homogenous, non stratified, deposit consisting predominately of silt, with subordinate amounts of very fine sand and/or clay.

Monocline – Beds inclined in a single direction.

Palagonite - A yellow or orange, alteration (oxidation) of basaltic glass. Often observed between pillow basalts - "Pillow Palagonite".

Pillow Structure – The peculiar structure exhibited by some lavas which consist of an agglomeration of rounded masses that resemble pillows.

Pothole - A hole generally deeper than wide, worn into the solid rock at falls and strong rapids by sand, gravel, and stones being spun around by the force of the current.

Rhythmites – Individual units of rhythmic beds.

Scabland - Used in the Pacific Northwest to describe areas where denudation has removed or prevented the accumulation of soil and the underlying rock is exposed of covered largely with its own coarse, angular debris.

Sill – An intrusive body of igneous rock of approximately uniform thickness.

Syncline – A fold in rocks in which the strata dip inward from both sides towards the axis.

Tephra – A collective term for all clastic volcanic materials which during an eruption are ejected form a crater or from some other type of vent and transported through the air (examples - ash, pumice, etc.)

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Videos

The Great Floods, Cataclysms of the Ice Age: WSU Pullman. The Story of the Channeled Scablands of Eastern Washington, the Formation of the Grand Coulee and Dry Falls. 13 minutes.

Ice Age Flood, Catastrophic Transformation of the West: Oregon Public Broadcasting, 7140 S.W. Macadam Avenue, Portland, Oregon, (503) 244-9900, www.opb.org 30 minutes.

Sculpted by Floods: KSPS-TV Public Television (Friends of Seven), 3911 South Regal, Spokane, Washington, 99223, (509) 354-7700, www.KSPS.org 47 minutes. $24.95

Mystery of the Megaflood: NOVA Presentation WGBH (Boston), Mail with payment to: Shop.WGBH.org, P.O. Box 2284, South Burlington, VT 05407. Phone Order (888) 255-9231. 56 minutes. $19.95. VHS or DVD.

Internet Websites and Related Information

Ice Age Floods Institute
www.iceagefloodsinstitute.org

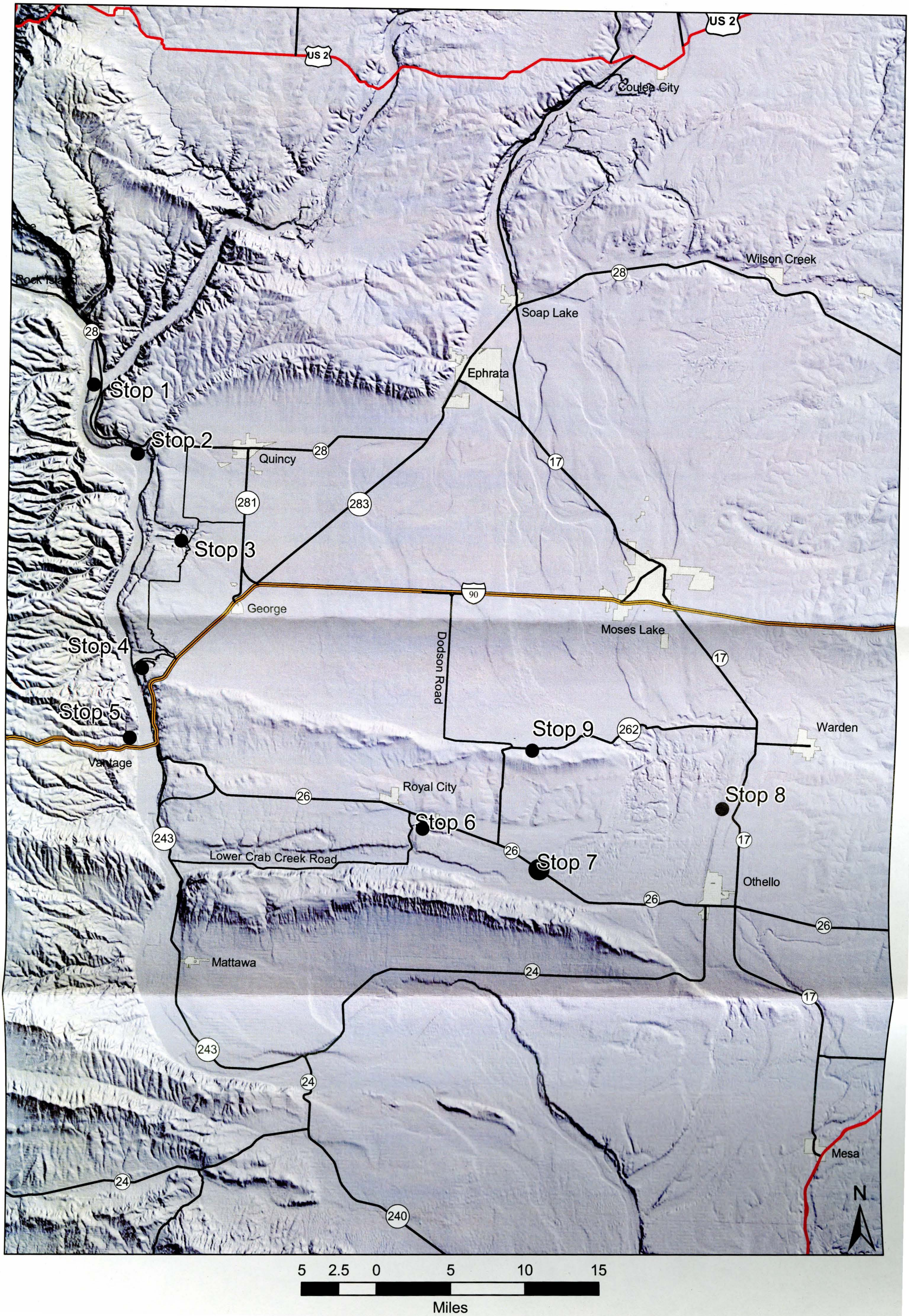
National Park Service-Ice Age Floods Study
www.nps.gov/iceagefloods

USGS Columbia Volcano Observatory
http://vulcan.wr.usgs.gov/Glossary/Glaciers/GlacialLakes/framework.html

Portland State University and US Forest Service Columbia River Gorge National Scenic Area
www.fs.fed.us/r6/columbia/main

Acknowledgements

I would like to personally acknowledge Bruce Bjornstad as a good portion of the information for this field guide was obtained from his previous work on the Ice-Age Floods. Thanks to Karen Atkerson for taking care of the trip logistics and to Ken and Susan Lacy for use of their residence as a great viewpoint for Stop 2 (West Bar). Thanks to Cathy Hillis and Kristina Thorneycroft for their expertise on constructing the digital terrane hill-shade maps. Also thanks to Marv McCamey and Bonnie Orr for their contributions of historical and botanical interest.



US 2
Coulee City
Rock Island
Wilson Creek
28
Soap Lake
Ephrata
Stop 1
Stop 2
Quincy
17
281
283
Stop 3
90
George
Moses Lake
Stop 4
Dodson Road
Stop 5
Vantage
Stop 9
262
Warden
Royal City
26
Stop 8
Stop 6
243
Lower Crab Creek Road
Stop 7
Othello
Mattawa
24
240
Mesa
N
5 2.5 0 5 10 15
Miles